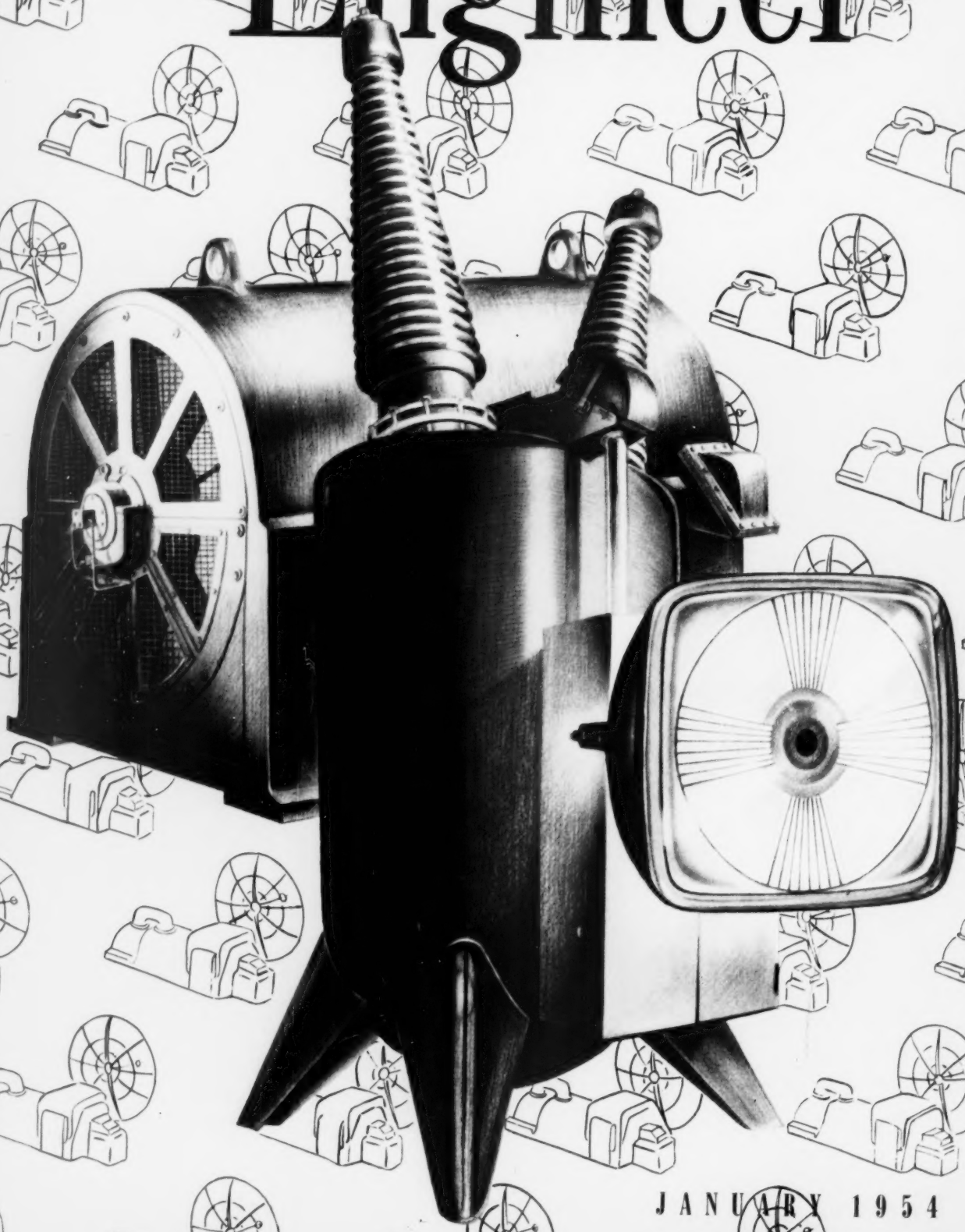
WESTINGHOUSE

Engineer



JANUARY 1954

ENGINEERING *Today* *Tomorrow*

Westinghouse invites you to join us in the year-end exercise of reviewing scientific and engineering accomplishment.

As usual we find the record is of great variety—in fact several varieties of variety. For example, it covers every step in the energy process from the steam-turbine inlet valve, through electric-power generation, transmission, distribution, and utilization down to the devices in the home for richer living. Then there is the variety of size from giant transformers of 300 000 kva, turbine generators of 250 000 kw, and circuit breakers capable of interrupting 25 million kva, to the humble and now much improved wall switch, and a glow lamp about the length and diameter of a pin.

Some developments are just coming to fruit—like the fluoroscopic image amplifier for which the first research was done ten years ago—while others of great industrial importance are just getting under way, such as the plans for the world's first power-station atomic-power reactor.

Some developments are entirely new, such as a water-cooled germanium rectifier, but by far most are improvements—in various orders of importance—of familiar equipments.

The review makes no pretense of being complete; the items are chosen to be representative of the work of scientists and engineers. It is incomplete by the omission of many interesting and important product developments and applications. But, also, nothing is said about one of the most important and least publicized phases of engineering—product cost reduction. One's first impulse might be to say that this work is of no interest to the purchaser of the product because seldom is the cost saving reflected in the selling price. Immediately, that is.

But nothing is farther from the truth. In times such as have prevailed for many years, in which cost per pound of materials and per hour of labor is rising steadily, only by cost-reduction engineering is the manufacturer able to hold the line—or nearly so. The cost of a transformer, or motor, or lamp bulb has risen only a fraction as much as the general index. Furthermore, in a time of stable or rising material or labor costs, a manufacturer has little opportunity to pocket more than a small percentage of the gains by product cost reduction. The intensive competition between electric-power equipment manufacturers sees to that.

Westinghouse is continually engaged in a large-scale product cost-reduction program, realizing that both the Company and the industry will gain thereby. We are proud of the successes attained. But our work in this direction is always subject to one overriding rule: reduce the cost of a product if possible, but never at the expense of quality. In fact more often than not, when design and manufacturing engineers learn how to make a product more cheaply, they also learn how to make it better. With pleasure and pride Westinghouse salutes the unsung work of its cost-reduction engineers.

This report also says little about the work being done for the future. In every phase of its business Westinghouse has stepped up its program for long-range development—development not just for 1954 and 1955—but for 1960 and 1965. In every division the entire attention of a group of engineers is on how to make major improvements in machines, devices, appliances—or how to create wholly new and useful apparatus to ease the burdens of man or to make his life more pleasant.

Backing up these concrete long-range product-development programs are greatly enlarged research and development facilities. Construction of a new home for the Company's central Research Laboratories is well under way, with occupancy planned early in 1955. The new laboratories are being located in a rural area some three miles from the present laboratories, which have become overcrowded with the many new fields of research undertaken.

A photograph is shown of the nearly completed laboratory for development and testing of steam and gas turbines, compressors, and associated power-producing equipment.

To bring a greater concentration of effort on the development of new alloys for high-temperature or high-strength application, such as steam and gas turbines, jet engines, high-speed generators, and so on, a new alloy laboratory is under construction on a farm-land site near Blairsville, a few miles to the east of Pittsburgh.

With these completely new research and development facilities and with numerous additions to its many product-development laboratories, Westinghouse is planning for the future of a greater industrial America, for easier living, and for better use of the increasing amount of leisure time.

A. C. MONTEITH
Vice President in Charge of Engineering

WESTINGHOUSE Engineer

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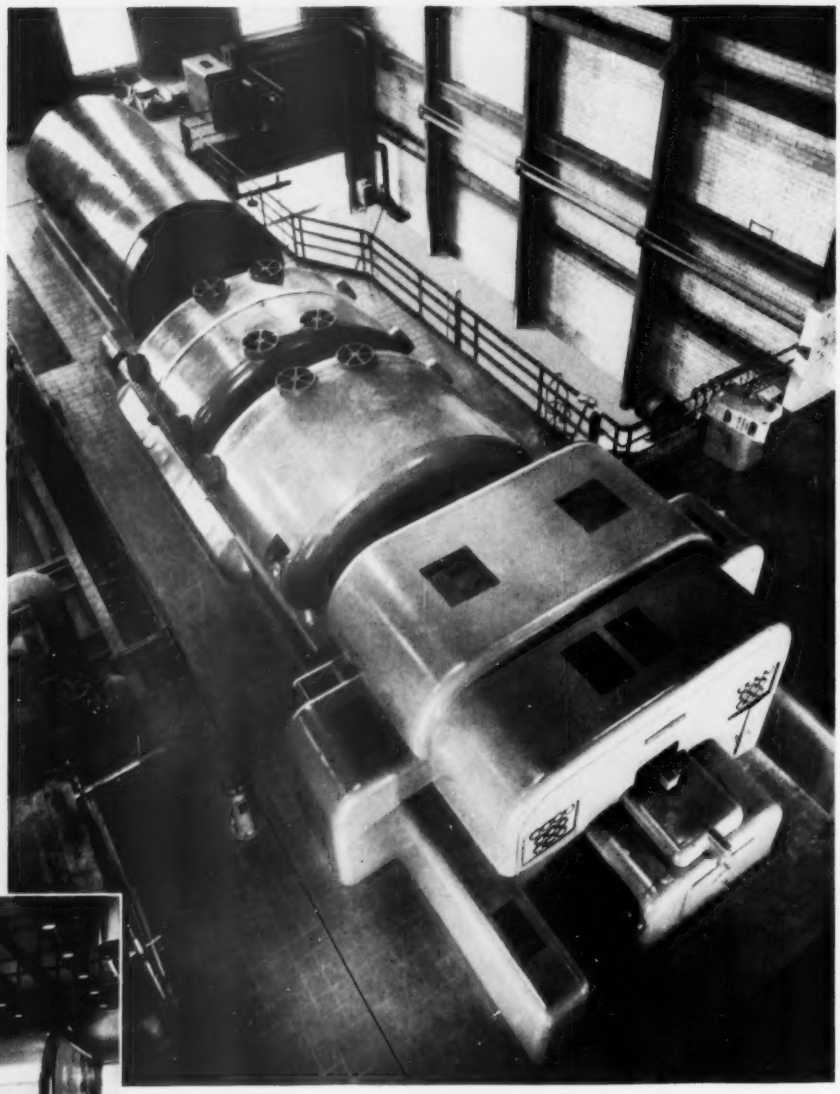
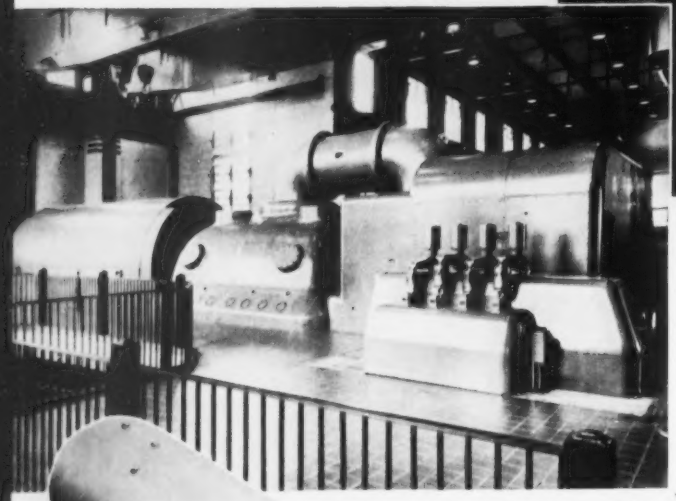
Turbines...

Steam-Turbine Progress

THE FAST PACE of construction of turbine-generator units has not let up. Neither has the rapid rise in sizes, nor the trend to reheat. In the year ending last August, Westinghouse began work on 18 new units larger than 10 000 kw, totaling 2 200 000 kw. Whereas the average size of individual turbines in 1951 was 54 megawatts, last year it was nearly 90 mw or an increase in two years of 66 percent. The average size, furthermore, is going up. It is expected to touch 92 mw this year and to be at least 100 mw in 1955.

Reheat, for the good reason of the fuel economy it engenders, continues to grow in popularity. In 1951 only ten percent of the turbines under construction employed





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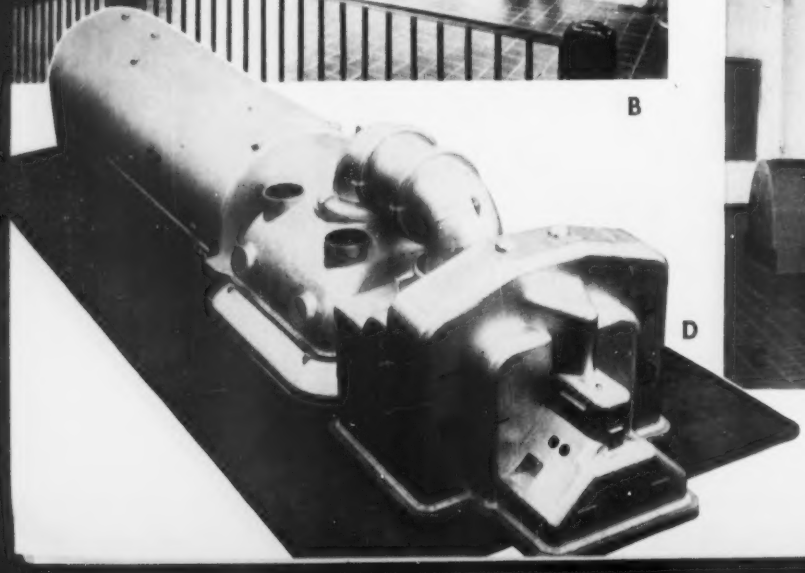

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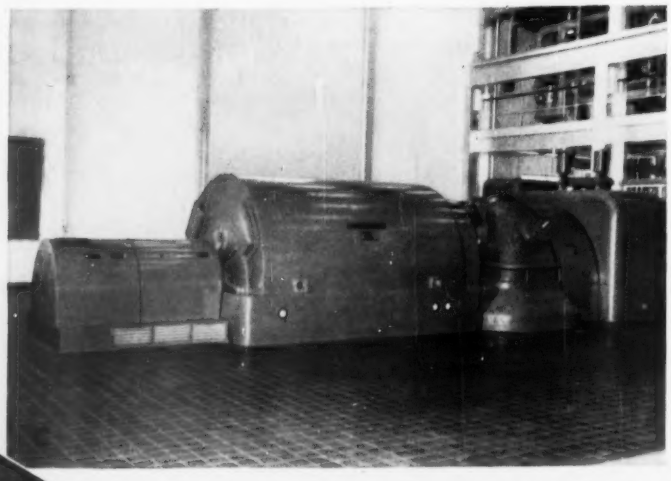


A *A*—A 125 000-kw turbine generator in the Delaware Station of the Philadelphia Electric Co. *B*—A 100 000-kw unit in the New Castle Station, Pennsylvania Power Co. *C*—A 15 000-kw impulse turbine, City of Brownsville, Texas. *D*—One 60 000-kw outdoor unit, Public Service Co. of Colorado.

reheat. Last August this percentage had risen to 87 percent of units 10 000 kw and over ordered in the preceding 12 months.

Several units now under construction are particularly worthy of note. The 185-mw, maximum-capability unit for Burlington Station of Public Service Electric & Gas Company of New Jersey is expected to go into service this fall. The inlet steam temperature will be 1100 degrees F, the maximum of any station. Also, it will be the largest tandem, 3600-rpm machine in the world, although it will be followed in a few months by one of 200 mw for the Philadelphia Electric Company, and in 1955, by the two 250-mw, single-shaft units in Gallatin Station, TVA.

Five extremely large cross-compound turbines are under construction, for areas where cold water is available to provide good vacuum and hence large exhaust steam volume. Four 217-mw units are being built for Ohio Valley Electric Corporation to help supply the atomic-energy development in southern Ohio. Largest of all machines now under construction is the 260-mw, cross-compound unit for Detroit Edison.

25-Inch Exhaust Blade—The first machines to use the new 25-inch exhaust blade are scheduled for delivery to Duquesne Light Company, Public Service Electric and Gas Company of New Jersey, and Philadelphia Electric Company. Ratings are 155 (double exhaust), 185, and 200 mw (triple exhaust), respectively. This is the first increase in blade length since 1948 when the 23-inch blade was introduced. The tremendous increase in size of machines makes this larger blade necessary.

The blade is not only longer but is also mounted on a 50-inch diameter rotor instead of one of 42 inches. Effective flow area to the condenser is increased by one fourth. In some applications, the flow through each end will exceed 400 000 pounds per hour. The blade itself weighs 9½ pounds and at 3600 rpm exerts a pull on the fastening of 105 000 pounds.

Development of the 25-inch blade began late in 1950. The problem was a major engineering undertaking expected to require five years for development, manufacture, and installation in the first machine. However, the increasing demand for power made it necessary to compress the time scale considerably. In fact, a machine using this blade will be in service 3½ years after the development was started.

One of the main problems in the design of such a blade is the determination and control of the natural frequency in four different modes of vibration. Highly involved calculations were first carried out on digital computers. After the design and tools were completed, a prototype group of blades was made and tested for stationary frequency in an assembly block. The results at this stage of the development appeared satisfactory. A complete prototype row of blades was then manufactured and assembled in a disc for a rotating test. In this test the rotating frequency of all modes of vibration was determined by electronic and optical methods.

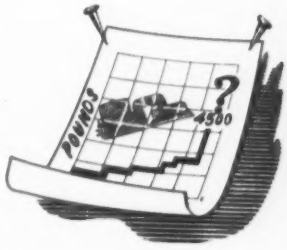
This test was a critical moment in the development program. Three of the four modes of vibration were entirely satisfactory. A 750 batting average is good in a baseball league, but not in blade-frequency control. Here a 1000 average is essential or disaster will result.

A search was now directed to the trouble with this one mode. A study of previous designs and test results indicated a definite difference in the relation of stationary and rotating frequency in the mode of vibration. This did not coincide with calculation. Rotor-disc flexibility was suspected as the cause. Fortunately, a better method of attacking this part of the problem had just been developed in connection with blade- and disc-frequency problems on the large compressors for the Tullahoma wind tunnel.

The new analysis was immediately applied by use of the digital computer. Disc flexibility was finally revealed as the cause of the difficulty. Then it became necessary to change the one mode of frequency without affecting the other three satisfactory modes. Analysis indicated that this could be accomplished by changing the profile of the disc itself. However, this change would increase the centrifugal stress in the disc and require a material of higher strength than had been previously produced in a forging of the size required. A steel supplier agreed to attempt the production of such a disc and was successful in about eight weeks. This disc was machined, the blades assembled, and preparation was completed for another rotating test—the second critical moment. After only a matter of a few days testing, complete success was evident. The rotor-disc profile alteration had changed the frequency of the only mode of vibration that was in trouble. The amount of the change was almost exactly as had been predicted by the new method of analysis.

The results represent a twofold accomplishment. The development of the largest 3600-rpm turbine blade was substantially completed and a new calculation method for blade frequency, including disc effect, had been verified.

Steam Turbines for Super-Critical Pressure Steam



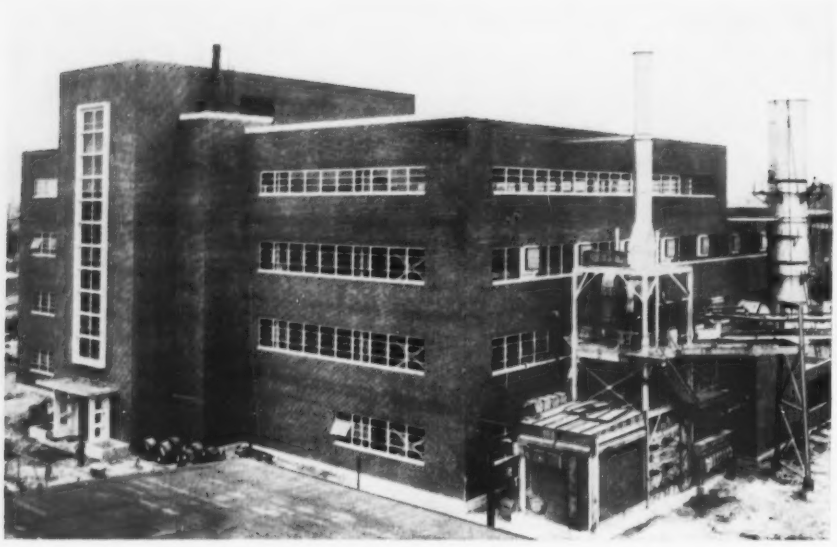
TURBINE STEAM conditions continually edge upwards. Several machines are operating at pressures between 2000 and 2400 pounds. All the largest machines now building are for 1000 or 1050 degrees, and this year Westinghouse will have a 1100-degree machine on the line.

With fuel costs showing no disposition to stop rising, the urge to lower heat rates is as strong as ever. So, what next? Engineers are taking a hard look at another increment in steam conditions. Increment, my eye! A long broad jump—up to a region of 5000 pounds and temperatures of 1200 degrees—even well into the extrapolation portion of steam tables.

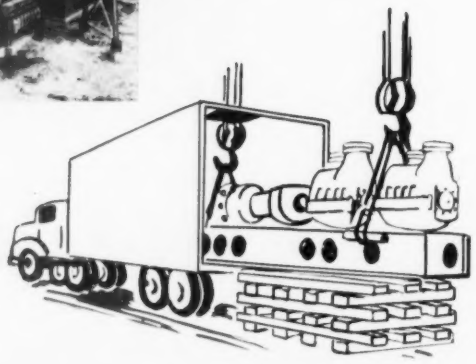
One reason for considering such a large increase in steam conditions is that a really big step is necessary to make appreciable gains. There is another reason. At 3206 pounds absolute pressure and at 705 degrees F, water and steam are equal in density. At this condition water is converted directly into steam without boiling. There is no change in volume, no latent heat of vaporization. For example, a boiler producing steam at a pressure of 3206 pounds or more needs no steam drum. The critical state is one to be avoided, with considerable margin, for an operating condition.

A careful study is being made of a 200 000-kw, 5000-pound turbine, with 1200 degrees initial temperature and two reheats. Early calculations indicate that by comparison with a machine of that rating, but operating at 2000 pounds and 1100 degrees, reheat to 1050 degrees, a gain in overall plant efficiency of five to six percent is anticipated.

The small gain in efficiency might not seem to justify the extra cost of construction that such a high pressure and temperature entail. However, when a few numbers are looked at, the complexion changes. Even a highly efficient 200-megawatt base-load plant consumes about 500 000 tons of coal per year. With fuel prices existing in some industrial areas, a company can afford to invest about a third of a million more in a 200-mw plant to gain one percent in efficiency!



Within this building will be created the ideas and data from which will come tomorrow's better steam and gas turbines, heat-transfer apparatus, compressors, and associated equipments. This is the Steam Division's engineering development laboratory being erected at South Philadelphia for use this year. Among the principal facilities will be a high-bay turbine test hall for development testing of steam turbines up to 1500 psi and 1100 degrees F; a compressor laboratory with a 60-foot long, closed-circuit wind tunnel; and individual laboratories for aerodynamic development of blading and gas-turbine combustors.

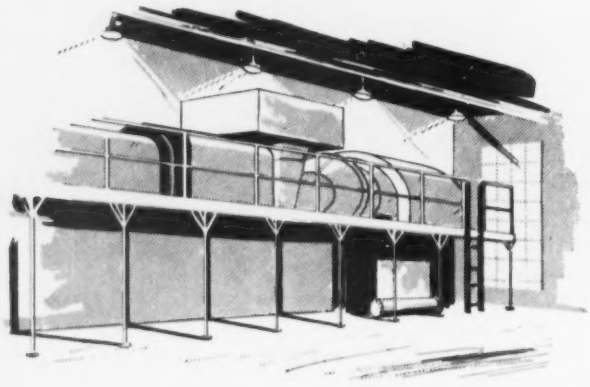


New Forms of Power Gas Turbines

THE GAS TURBINE is beginning to cash in on its small volume and weight per horsepower. This is indicated by a pair of mobile gas-turbine power plants, one on rails, the other on rubber tires. A complete 5000-kw power plant is being built into two railroad cars. One car contains the gas turbine, a-c generator, and power-plant auxiliaries. The second houses the switchgear, transformer, and protective equipment. At least three cars would be required to house the equivalent diesel-powered plant. The gas turbine is essentially a duplicate of the 5000-kw plant that has been running for several months developing electric power for West Texas Utilities Company, and which, as of October first, had accumulated 4600 hours of service. It is a simple, open-cycle, single-shaft plant to give a thermal efficiency on LHV fuel of 20 percent. The gas turbine occupies a floor space of 17 by 7½ feet and weighs 20 tons.

The two-car rail plant is being built for the U. S. Army for use in military field operations. Accordingly, it develops power at either 50 or 60 cycles. (The turbine operates at constant speed, 5740 rpm; the different speeds are obtained by gear changes.) This was achieved by using a low magnetic flux density, permissible because a low short-circuit ratio can be tolerated on 60-cycle duty. The generator also is required to be shielded against producing radio interference.

A smaller mobile plant built into a truck body is an 1800-hp, simple, open-cycle turbine driving air compressors for a U. S. Army application. This is virtually a carbon copy of the gas turbine used in a locomotive and in gas-line booster compressor service. The turbine weighs 20 000 pounds, and occupies a floor space of 21 by 5½ feet.



A higher capacity unit of this small, simple machine is in service. It is a mechanical-drive machine rated at 7000 hp. It was designed to incorporate improvements suggested by experience with the 1800-hp prototype machine and to make it possible to build and maintain at lower cost. The casing of the compressor, combustor, and turbine is built with sufficient strength to maintain alignment of rotating parts. This eliminates the need for any additional bedplate under the combined unit. To facilitate maintenance, a single horizontal joint runs the length of the entire casing. When the upper half of the casing is lifted, all rotor and stator elements are exposed. The compressor and turbine rotor are constructed as a single unit with two end bearings mounted on the outside of the casing. The turbine rotor is built up of a series of discs held together by bolts.

A 5000-hp, compound, open-cycle plant is being erected for test. This plant differs from the single-shaft plant in two respects: First, a regenerator is added to utilize some of the waste heat leaving the turbine exhaust to preheat the air for combustion. Second, the power turbine is mechanically independent of the compressor and its turbine.

A regenerator increases the thermal efficiency by recovering about 75 percent of the available exhaust heat. It is, however, a large and heavy element, weighing about five times that of the gas-turbine power plant itself. The divided shaft also adds to the complexity. The net result is that the total cost of the dual-shaft plant per horsepower is about 40 percent more than for the single-shaft plant. This extra cost and complication are

justified only when fuel costs are high and the greater flexibility of operation is worthwhile.

A still larger, more efficient plant, of 15 000 kw, is under construction. It, too, has two shafts, which with heat-saving devices, such as a regenerator and intercooler, will give it a thermal efficiency of 28 percent.

Milestones in Nuclear Power

THE BURGEONING atomic age has three new landmark dates. One was last March 30. On that day the prototype submarine reactor (STR) at the National Reactor Testing Station in Idaho reached criticality, i.e., the chain reaction became self-sustaining. The second date came a few weeks later. On May 31 the reactor was placed in power operation. In the words of the Atomic Energy Commission, "substantial amounts of power" were developed.

These two dates signal that the world's first nuclear-power reactor—designed for the sole purpose of producing power in quantity and not as a by-product of some other main objective—is in operation. While some other reactors have produced minor amounts of electric power, mostly to prove the point, the output of the submarine reactor is measured in thousands of kilowatts of the same order of magnitude as some of the smaller electric-utility power stations.

The third important new date is yet to come. The launching of the *Nautilus*, the world's first atomic-powered submarine, is scheduled to occur on January 21. This will take place at the Groton, Conn., yards of the Electric Boat Division of General Dynamics Corporation. The *Nautilus* is being equipped with a pressurized water reactor similar in all major details to the Idaho prototype.

Another milestone decision was made last year by the Atomic Energy Commission. In October it announced that a program had been started to construct a full-scale power reactor of the pressurized water type, with Westinghouse selected as the contractor because of its previous experience with this type of reactor. This power reactor will produce a minimum of 60 000 kw of electrical energy, possibly much more.

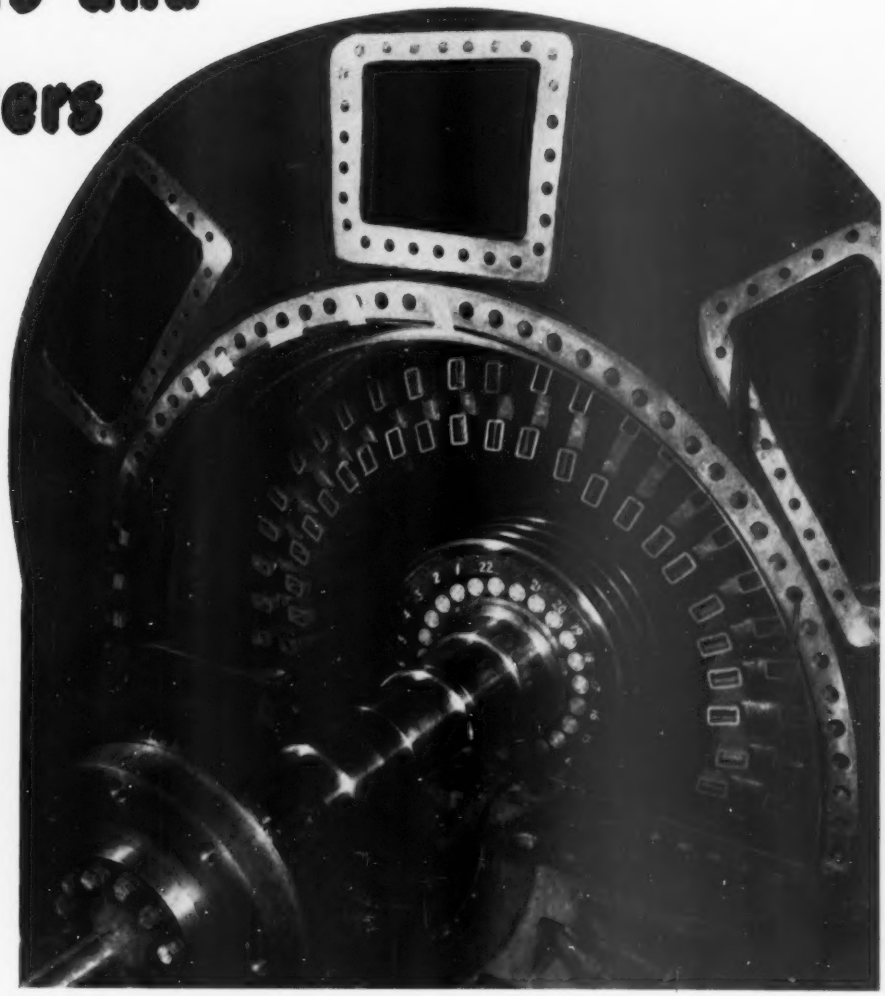
A new factory has risen on a golf course in Harmar Township, near Pittsburgh. This plant is of more than ordinary significance. It is believed to be the first privately owned plant solely to supply equipment for atomic-power industries.

Generators and Condensers

Developments in Turbine Generators

THE FIRST GENERATOR employing the principle of inner cooling in both stator and rotor was tested last year. This was a 100 000-kw machine for the Niagara Mohawk Power Corp.

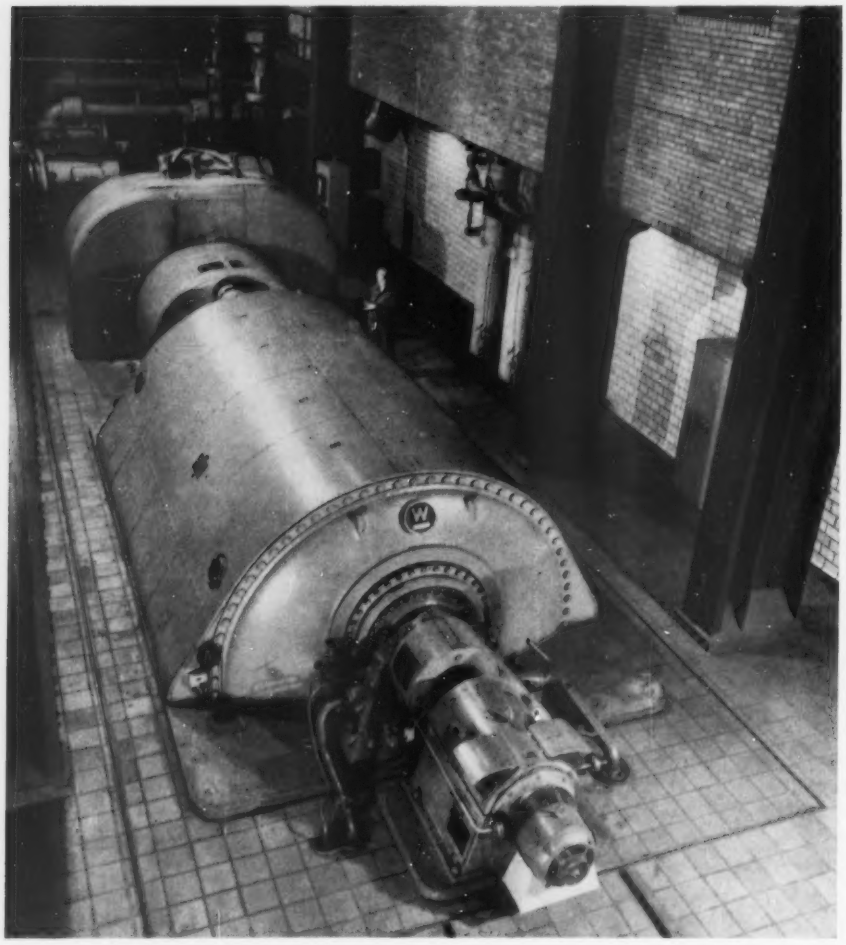
Test results fully demonstrated the highly effective and efficient means of cooling. Furthermore, the way was pointed to the possibility of constructing units having ratings of hitherto unbelievable magnitude. This unprecedented broadening of the horizon is possible since the heat dissipation rate from the windings at safe temperature is measurably increased with every increase of the hydrogen pressure. This contrasts dramatically with conventional machines that have a relatively low fixed limit of heat dissi-



This 100-mw unit, of the Niagara Mohawk Power Co., is the first machine to employ inner cooling.

pation through the insulation, regardless of gas pressure.

While the "inner-cooled" generator may appear daringly new, the design is unique only in the novel manner of application of often proved principles. Actually, there is no radical departure from conventional design standards or construction materials. Ventilation of stator coils, for example, has been accomplished by establishing a pressure difference in the end-winding zones, so that cooling gas flows freely from one end to the other through the cooling passage within the coil without the encumbrance of plumbing. Where the gas enters or leaves a coil, the winding is protected with a silicone rubber cap.



This West Penn Power Company generating unit has a magnetic-amplifier excitation system.

Machines ventilated by the inner-cooled principle show signs of wide acceptance. This construction will be offered for ratings of about 100 000 kw and larger. As of October first, 13 units totaling 2¼ million kw were on order.

43-Inch Rotor—Turbine generators with the new larger rotor have been running for several months. This is the 43-inch diameter rotor, three inches more than the previous largest. One of these is the 125 000-kw, 85-percent power factor, 0.80 short-circuit-ratio machine in the Delaware Station of the Philadelphia Electric Company, and others are in TVA's Shawnee Station and the Sunbury Station of Pennsylvania Power and Light Company, rated at 135 000 kw, 90-percent power factor, 0.9 short-circuit ratio. Considering their high short-circuit ratio, these are the largest capacity, single-shaft, high-speed machines now in service.

High-Voltage Terminals—As the current output of generators has increased, the matter of terminals has become a problem. Until recently the highest capacity bushing was 6000 amperes. It was contained in an oil-filled porcelain. On high-amperage machines this has sometimes required two terminals in parallel to handle the current. This situation is now relieved by a high-strength, zircon-porcelain terminal that can carry 10 000 amperes. The bushing is no larger than the 6000-ampere unit, a part of the increased capacity coming from a ventilation system that forces cooling gas over the terminal area. The copper is purposely exposed instead of covered with insulation. This gives better heat transfer. The bushings, furthermore, are the dry type, which eliminates all risk of oil leakage, a matter of importance because these porcelains are subjected to inherent 120-cycle machine vibration.

When current transformers are incorporated in the machine terminals the practice has been simply to lengthen the bushing to provide the mounting space. The steel portion of the new terminal has been reshaped into a cone that can house the current transformer. Accordingly a transformer does not add to the length of a bushing. A short bushing is desirable because of the vibration stress on a cantilever member and because the shorter length gives the bushing greater strength against short-circuit forces.

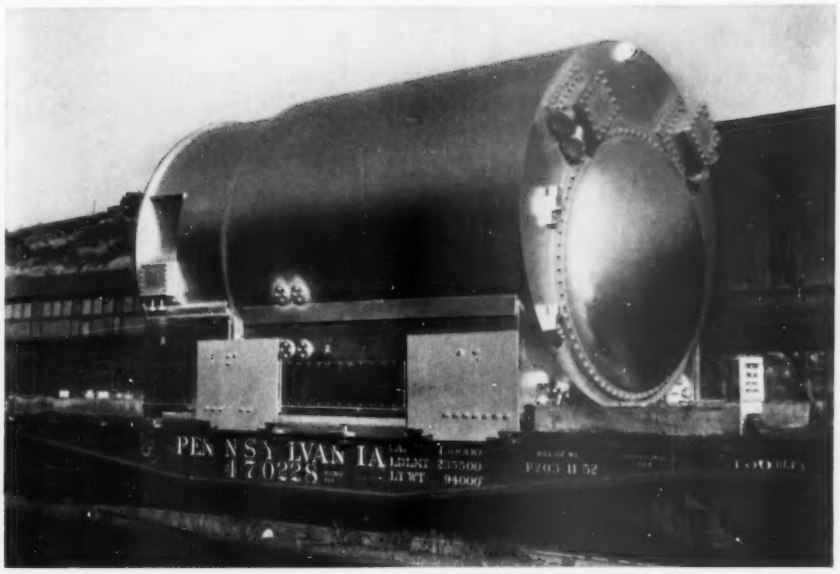
Geared Exciter—The direct-connected turbine-generator exciter has a performance record that is long and outstandingly successful. However, turbine generators are now requiring more excitation kilowatts than these high-speed machines can provide with good commutation. Some generators already are requiring 1100 kw and larger ones are in prospect. This has led to the development of an improved geared exciter for use with generators beginning with about 90 000 kw. Since a speed less than 3600 rpm had become necessary, a relatively low speed was chosen—897 rpm, with a commutator speed of 5500 fpm, to give maximum benefit.

Magnetic-Amplifier Excitation—Seldom has a development been accepted so unanimously before field trials as the magnetic-amplifier excitation-control and voltage-regulation system for large a-c machines announced in the fall of 1952. At the time of announcement, all but one of the purchasers of the large machines Westinghouse then had under construction elected to adopt the magnetic-amplifier system. All large machines purchased since, for which this type of excitation is suitable, are being so equipped.

Synchronous Condenser

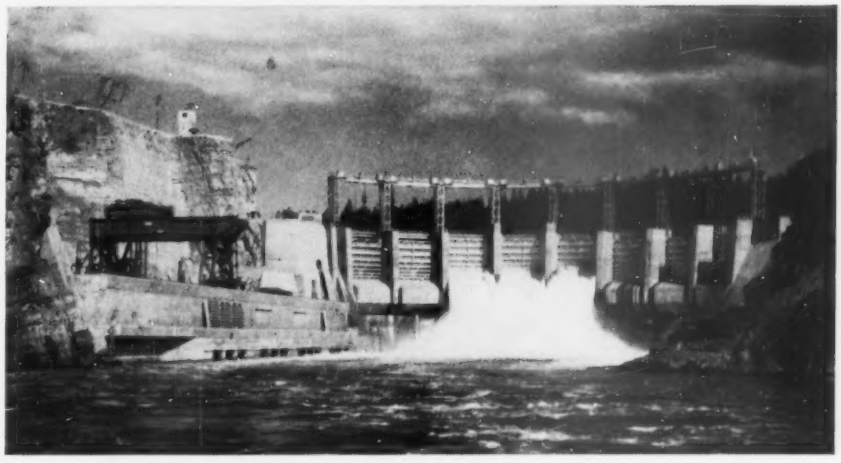
The synchronous condenser has been improved in several ways. Previously six lead bushings have been required, one pair for each phase. Now there are but three. A new porcelain housing makes it possible to contain each neutral within its phase terminal. This concentric-terminal construction has the additional advantage that it eliminates the heavy non-magnetic plates welded into the frame between neutral and phase leads. The d-c field leads are also contained one within the other, which reduces the gas seals from two to one. The oil content of each bushing has been reduced to about one eighth. It is now only about a quart.

Removal of the rotor for inspection or maintenance is much simplified. A special rigging has been devised that can be fastened to the rotor and acts as a track on rollers by which the rotor can be shifted. It has been customary to place the hydrogen apparatus for a synchronous condenser in a pit below the machine. The hydrogen auxiliaries have been redesigned and packaged for mounting in steel cabinets that can be located in the yard area at the most convenient spot. The fact that this equipment is factory assembled into convenient packages reduces assembly time on location. Above-ground location means there is no pit to be kept dry, less pumping is required, and the condenser foundations are both simpler and cheaper.



Cabinet Gorge

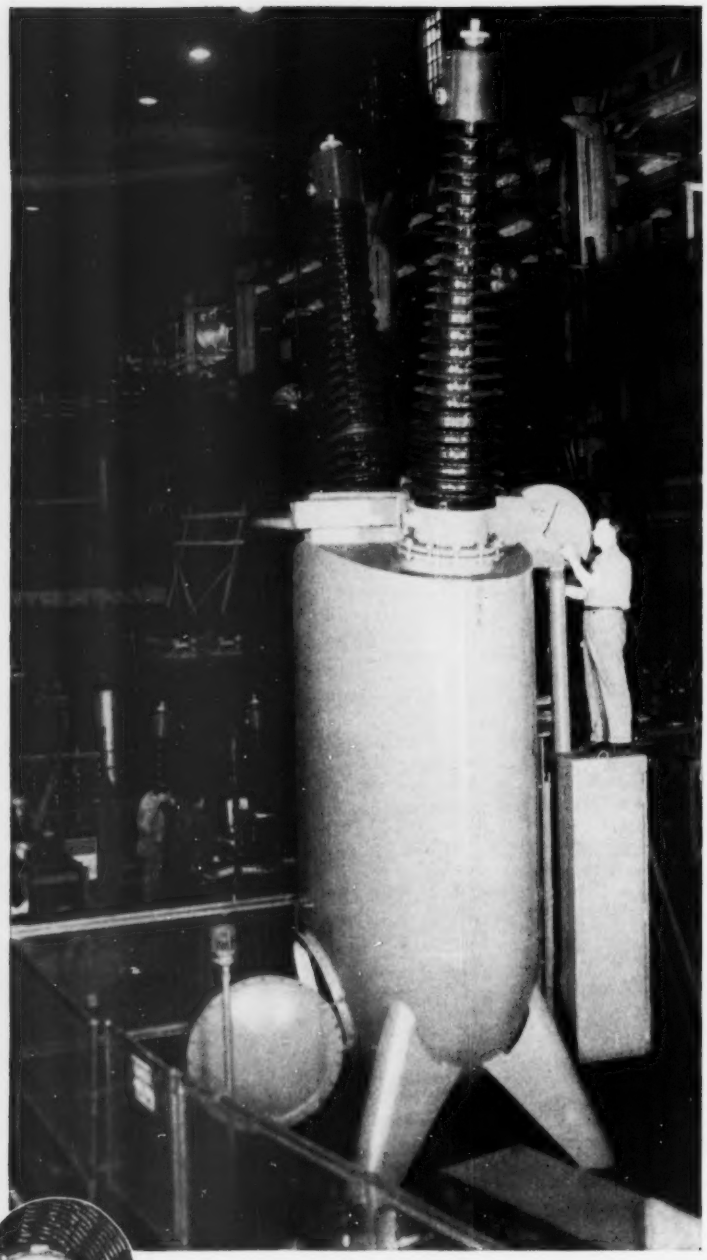
The Cabinet Gorge hydroelectric development on the Clark Fork River in northern Idaho was completed last year by the Washington Water Power Company. The first of four 50 000-kw generating units was on the line just 21 months after start of construction, an extraordinary achievement in face of unusually severe conditions of weather, terrain, and the wild nature of the river. The task of diverting the river and pouring concrete for the 208-foot-high, 600-foot-long dam was accomplished in a single season between river flood stages. The fourth unit went into service in August.



Induction Generators

Induction generators of any size are rare. This T. W. Sullivan Station of the Portland General Electric Company consists exclusively of induction generators, containing twelve 1200-kw units. The station is also of historic interest as it is on the site of one of the first hydroelectric plants in the world. Here, at Willamette Falls, Oregon City, in 1895, three 450-kw, 33⅓-cycle, 6000-volt, revolving-armature generators were placed in operation.

Circuit Interruption and Lightning Protection



The bushing for the 330-kv breaker (*right*) is 18 feet long and weighs two tons. The outer casing is about eight feet tall, corrugated for extra creepage, while the inner end is covered with a one-piece porcelain unit over four feet long. The bushing is able to withstand the 1300-kv impulse test.

Don't Ask for a Bigger Breaker Unless You Want It

A CONFERENCE was held one day last spring by engineers of the Ohio Valley Electric Corporation and Westinghouse. The subject was the circuit breakers needed for the new 330-kv system to serve the plutonium-production plant being built in southern Ohio. Substantial agreement had already been reached to build oil circuit breakers of 15-million-kva interrupting capacity. (The highest capacity oil breakers in existence are 15 million kva at 230 kv.)

Near the end of the discussion the conversation, in effect, went as follows. The leader of the Westinghouse delegation turned to the power-system men and said: "Well, gentlemen, are you satisfied that these breakers will meet your system requirements?"

There was a pause before one of the system planners spoke. "As a matter of fact, we wish we could get a still higher interrupting capacity."

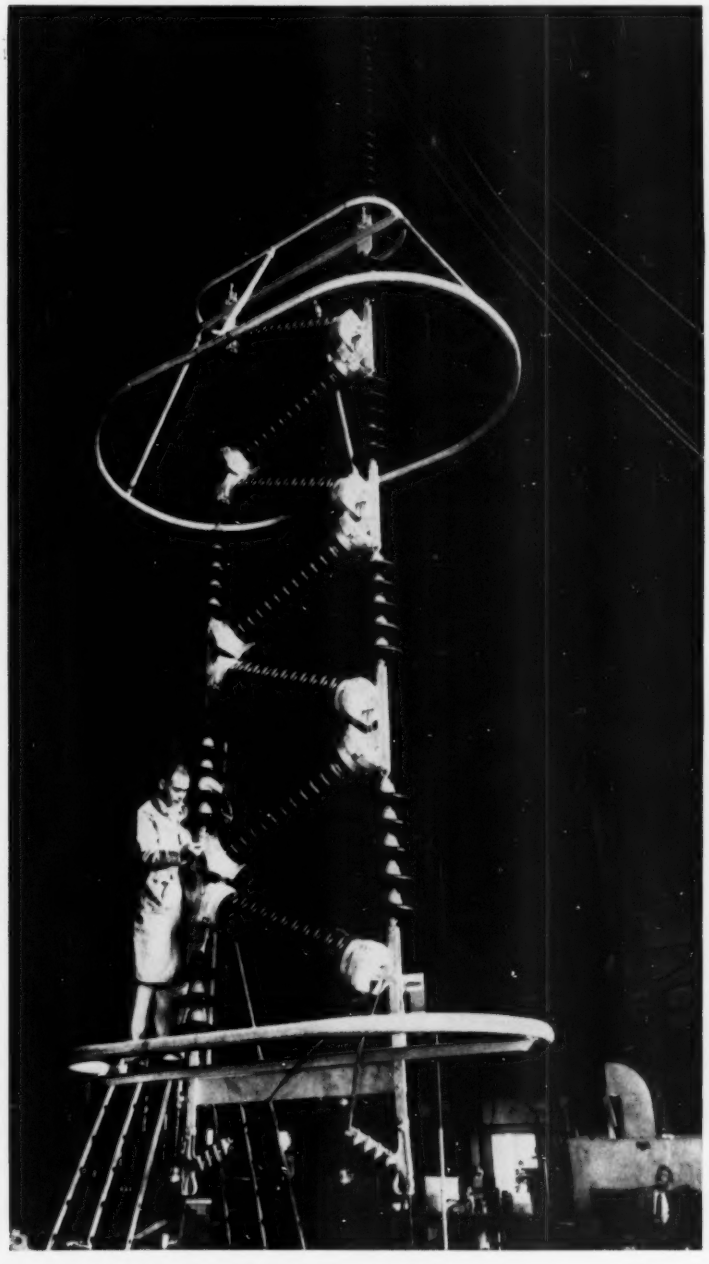
"How much more?" he was asked.

"Well," he replied in a manner that suggested he felt there was no harm in asking for plenty, "25 million kva would give us a more comfortable margin."

"If you feel you need it, we are ready to build it," replied the Westinghouse spokesman.

Not quite so quickly as that, of course, but the decision to build breakers so far in excess of any past capacities was made with little hesitation. It bespeaks the confidence the design engineers have in themselves and their facilities to cope with such enormous short circuits, as well as the confidence of operating engineers in the ability of circuit-breaker designers.

One pole of these 35 breakers has undergone high-power laboratory tests. The interrupter is designed for fault clearing in 3 cycles and for reclosing in 15 cycles (20 is general practice). The tank is a modified Watch Case design, in which the shape is contoured to contain but little oil that is not serving a dielectric function. The three tanks for one breaker require about 10 000 gallons —which compares with 6800 gallons for a 3½ million-kva, 230-kv breaker of four years ago.



Meeting the requirements for a 330-kv system, this 258-kv arrester posed no problems other than adding standard porous-block (SV) units to raise the voltage rating. Suspension mounting simplifies erection.

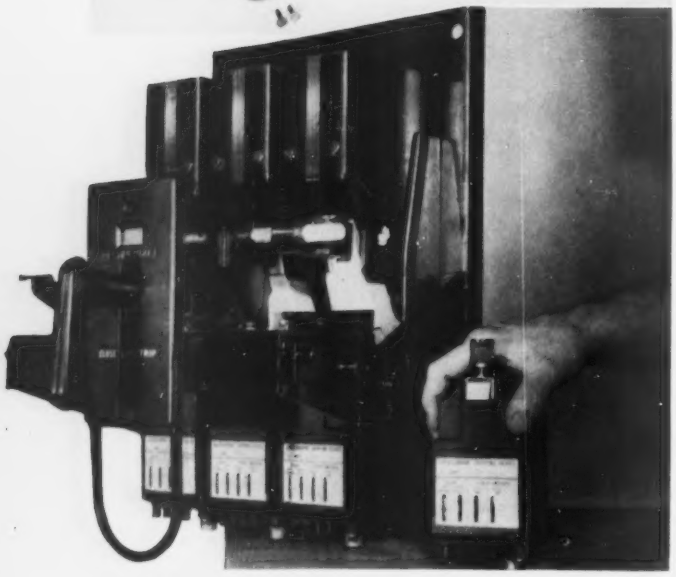
6000 Amperes from a 5000-Ampere Air Circuit Breaker

OCCASIONALLY, but not often, a circuit breaker is needed for a power station on a 14.4-kv generator bus that is capable of handling 6000 amperes continuously. The largest standard air circuit breakers available for this voltage have a continuous current capacity of only 5000 amperes. To soup up this breaker for the higher current, engineers have taken a leaf from the book of transformer experience. A set of fans is located in the bottom compartment to provide a blast of cooling air across the contacts when necessary. "When necessary" is determined by a set of thermostats that measure the differential in temperature between the inside and the outside.

A Small Arrester with a Big Job

A NONDESCRIPT little mouse once freed a roaring lion from a rope net—and proved to his fellow beasts that even a mouse has his moments of glory. Substitute a low-voltage, signal-circuit arrester (RVS) for the mouse, and a train for the lion, and a similar parable could be written. The small arrester protects low-voltage railway signaling circuits from lightning—thereby helping trains run on schedule.

This arrester consists of a series gap, formed by prongs on the rim of a brass plate separated a short distance from a dish-shaped backing



plate, and a wafer of Autovalve porous-block material, all contained in a horseshoe-shaped transparent plastic.

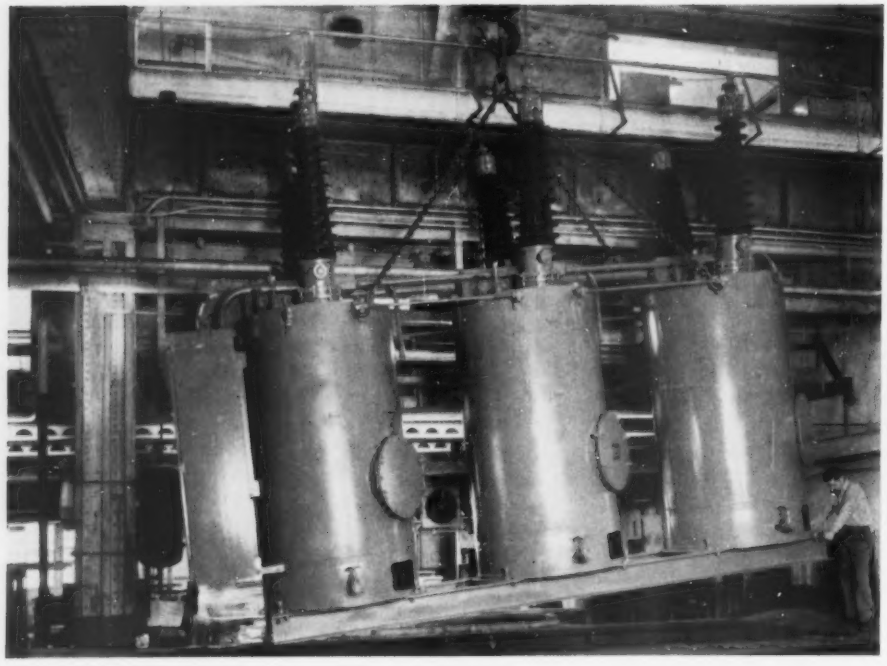
The seal between the plastic housing and base has been improved—by providing more sealing surface and using a varnish seal. Component parts have been mechanically combined, resulting in a more rugged unit. The backing plate used in conjunction with the spark gap has been designed to prevent metal vapor of the arc from accumulating on the Autovalve block and diminishing its effectiveness. The series gap has been made more visible. Electrically, the unit is the same as ever—single pole, 175 volts alternating current, 75 volts direct current, 10 000-ampere lightning-current capacity.

A More Versatile Overcurrent Trip Device

CIRCUIT BREAKERS used with a number of motors driving the many auxiliaries in a powerhouse, for example, have a good deal of quick "thinking" to do. On the occasion of a fault, each has to decide whether it should open immediately or give another breaker closer to the spot in trouble a chance to act first. Also a breaker must distinguish between a nearby short circuit and a heavy overload.

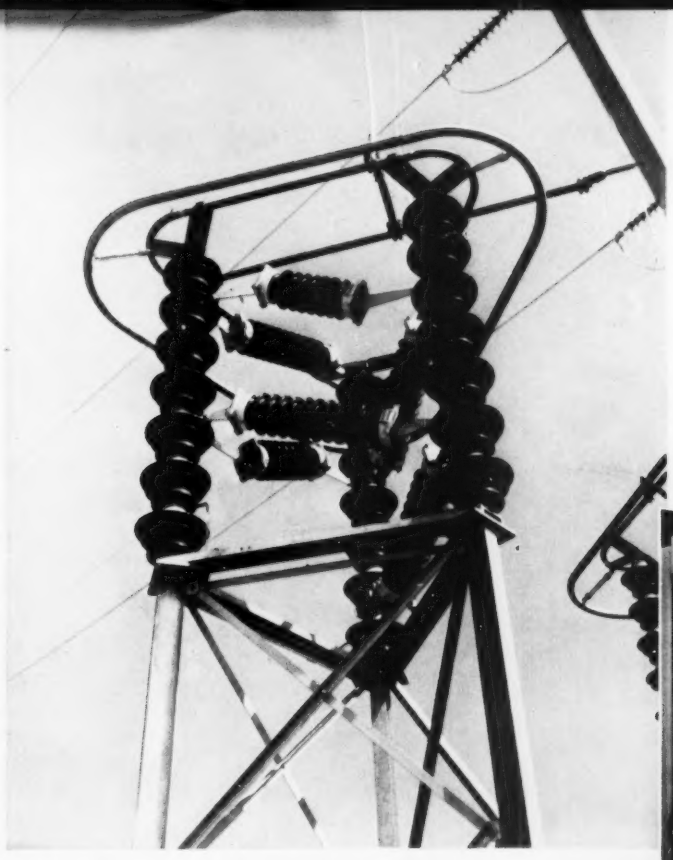
The gadget in the breaker that does the "thinking" is the overcurrent tripping device. A new one is considerably improved in many ways. The timing device, which coordinates its tripping action with that of other breakers, consists of an air chamber with external adjustment. The one before has been a good performer, but comprised a heavy fluid permanently sealed in a chamber with no way to adjust it either in the factory or in the field. Now, one precisely made valve—the heart of the device—takes the place of two. The overcurrent-trip is housed in a Micarta case, which provides ample insulation between coil and core. A new magnetic air gap produces the optimum in force-travel characteristics needed to deliver maximum tripping force for a given size and weight.

The device has no needle valve that might become clogged. Furthermore all air coming into the device is filtered. The complete device has four adjustments so that a wide range of performance characteristics can be obtained.



138-Kv Breaker Shipped as a Unit

Like most major electrical equipment, circuit breakers of higher rating are being shipped completely assembled at the factory ready for placement in service as a unit. Oil circuit breakers of 115- and 138-kv categories have been shipped completely assembled, with bushings in place, where rail clearances have permitted. Each breaker—all three tanks—is handled, shipped, and set on its foundation as a unit. This has been made possible by several construction improvements, particularly by the smaller size tanks resulting from the multiflow De-ion grid interrupters and the use of a structural-steel base for all three tanks. Large savings in erection labor and time are among the benefits.



Drawout Circuit Breaker

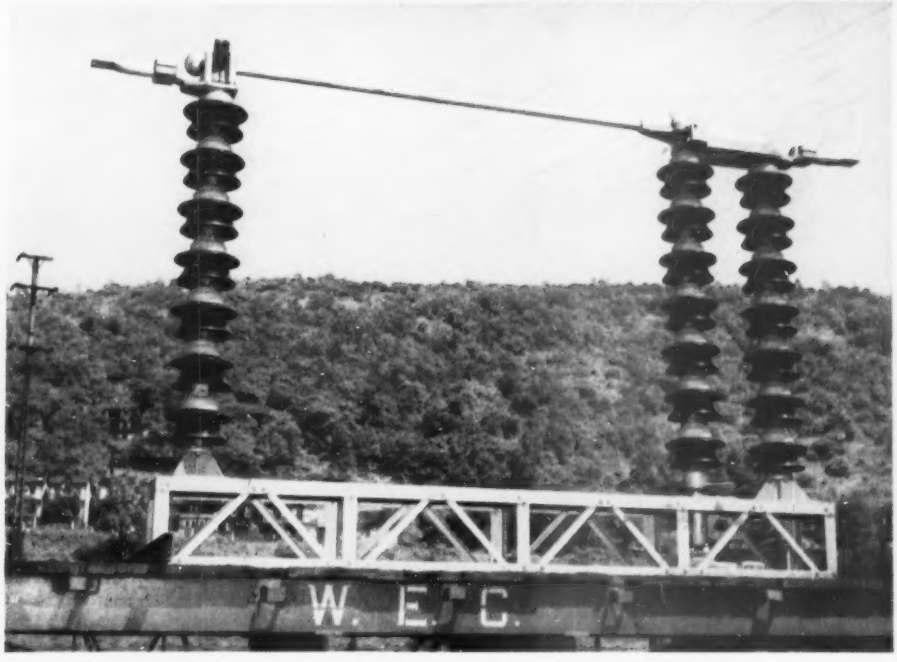
The drawout air circuit breaker for metal-enclosed switchgear comes in a new size. It employs the new, adjustable overcurrent trip element. This removable-type breaker, on wheels for easy inspection or maintenance, has a continuous current rating of 4000 amperes at 600 volts a-c, and can interrupt a short circuit of 100 000 amperes. Previous breakers of this rating were larger, using a space 60 inches high.

A Low-Height, Self-supporting Arrester

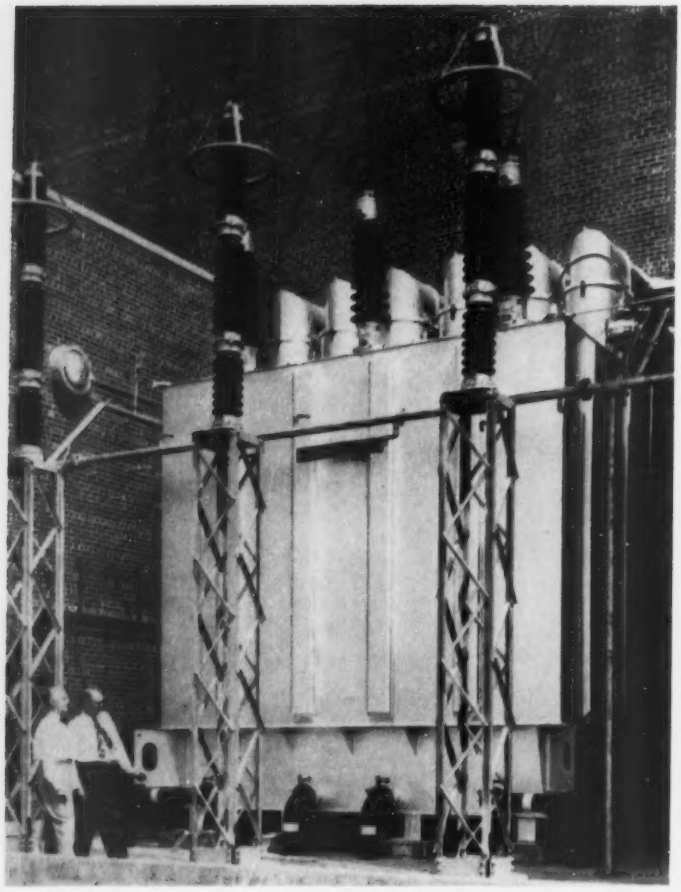
ENGINEERS HAVE accomplished two things by "winding up" the new 195-kv arrester spiral fashion—made it mechanically self-supporting and saved about ten feet of overhead clearance, a valuable commodity in substation design. Three insulator columns support six arrester units. The new arrester (SV) for 230-kv service is about the height of a transformer bushing of the same voltage class. This means a short lead between transformer and lightning arrester.

A Switch with a 13-Foot Blade

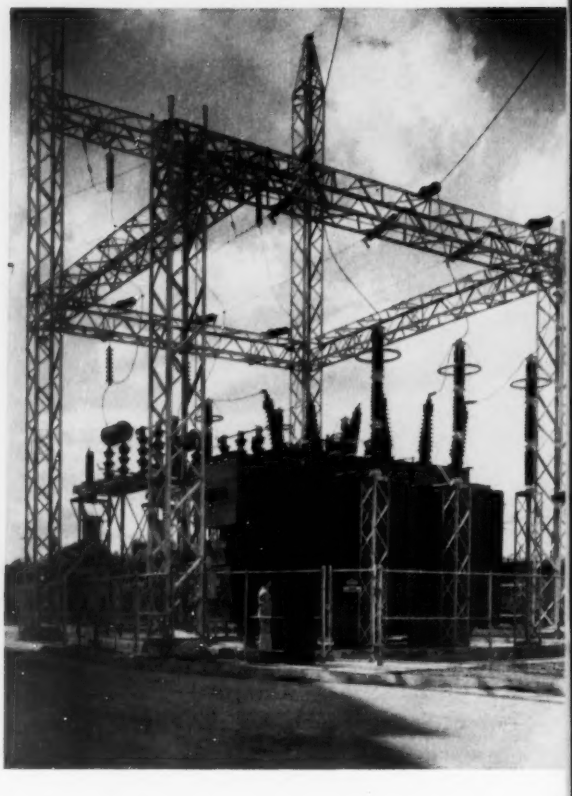
The disconnecting switch developed for 330-kv service follows the construction used with success on systems up to 220 kv. But for this voltage and for a particularly high current it becomes a mechanical giant. The blade is 13 feet long and stands on 10-foot stacks of insulators. The continuous current rating is 1600 amperes, which is extremely heavy for so high a voltage. The switch has withstood currents of 70 000 amperes in high-power laboratory tests. All moving parts are well rounded or enclosed; no external shielding is needed. At 400 kv the switch shows no visible corona and a low radio-influence voltage. It successfully withstands impulses of 1300 kv (BIL).



Power Transformers



The largest transformers in service anywhere are four 190 000-kva, Detroit Edison Co. units. They were shipped upright in their own tanks, with oil.



This regulating transformer passes power back and forth at the Canadian border, Detroit. It is a 150 000-kva tie between Detroit Edison Co. and the Hydro-Electric Power Commission of Ontario.

The Booming Power-Transformer Business

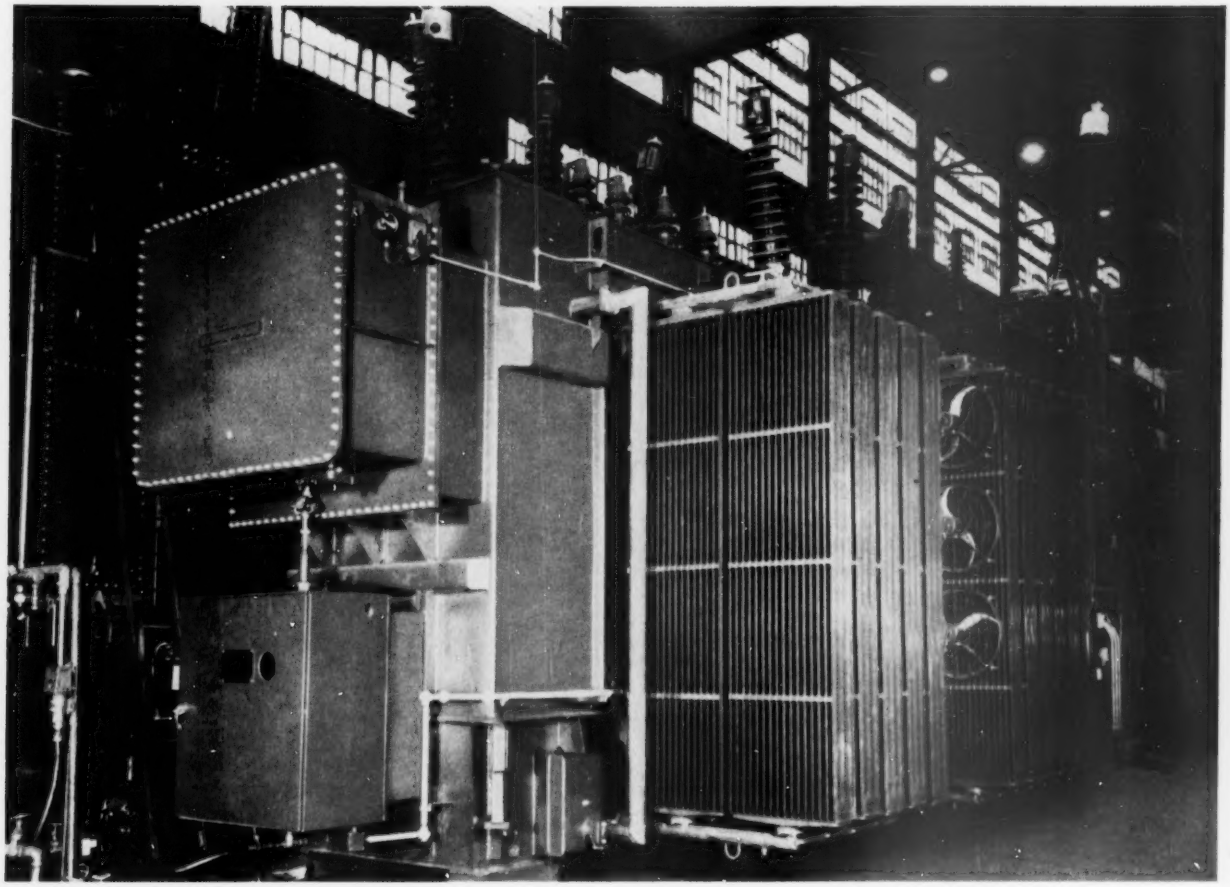
WHAT IS GOING on in the power-transformer world is suggested by the fact that as of last October 1 the power companies of this country had purchased, from five manufacturers, 297 transformers of 100 000 kva and larger. Among the 169 of these giants produced at Sharon are some particularly interesting specimens. Biggest of all is one of 300 000 kva for Detroit Edison Company. This forced-oil-cooled unit, 115 kv, 3 phase, will be shipped in a single-piece tank, with only the bushings and coolers removed.

Other large units presently undergoing construction are four of 220 000 kva at 161 kv, for TVA. These are forced-oil, forced-air-cooled machines.

Equipments for the new higher line voltage—330 kv—are shaping up. The delivery of the first four of twelve 150 000-kva, 330-kv autotransformers for the American Gas and Electric Company was made last summer. Also, for the atomic-bomb material plant in southern Ohio, six 100 000-kva, 330-kv transformers are under construction. These will have load tap-changing equipment.

Regulators—In the same breath with large transformers should be mentioned large regulators. The largest ones now are two 150 000-kva transformers being used to tie together the systems of Detroit Edison, the Hydro-Electric Power Commission of Ontario, and the Consumers Power Company. The load tap changers on these units have unusually high current capacity as the regulation per step is 15 percent, meaning that load is controlled in large steps. Of these two units one has a primary voltage of 143 kv and the other side regulates to 125 $\pm$18 kv. The second has one line at 120 kv and the other 125 $\pm$ 18 kv. Size of these units is indicated by these unusual dimensions: 30 feet long horizontally, 20 feet wide, and 22 feet to top of bushings.

Maximum Size—One wonders if these giant transformers have not about reached the limit of shipping weight and dimensions. Transformer designers say "no." Even with present cars and present transformer construction (i.e., a form-fit tank) a 250 000-kva, 230-kv or a 180 000-kva, 330-kv unit could be shipped in its own tank in nitrogen. Indicative, however, of the part railroad cars play in this growth is the fact that high-voltage transformer ratings can be increased



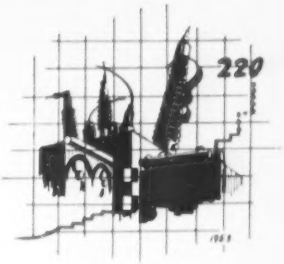
This 150 000-kva power regulator sets a record in kva rating. It is 20 feet wide, 30 feet long, and 22 feet to the top of the terminals.

up to two kva for each additional pound a car can carry.

Insulation Level—The trend in transformer basic impulse insulation level is downward. Up to 1930 the industry-accepted BIL for 230-kv units stood at 1050 kv. It was then reduced to 900 kv. Recently some power companies are authorizing BIL's of 825. The reduction in insulation this provides decreases in both transformer weight and cost of eight to ten percent. This reduction in allowable transmission-system practices and equipment—particularly lightning arresters—can now be relied on to prevent the higher surge voltages from reaching the transformer.

Surge Testing—Power transformers on a selected basis have been impulse tested for several years, using both the applied full wave and the more severe chopped wave. These tests have proved so searching that production facilities at Sharon have been modified to permit all power transformers over 10 000 kva and 69 kv to be impulse tested, as part of the production quality-control program. To do this, a third surge generator—capable of delivering surges up to 2.4 million volts—has been built into the production aisles, supplementing existing 1.2 and 3.6 million-volt generators.

High-Pressure Radiators—In the designer's book a gasket is to be used only when one can't avoid it. On this basis designers of power-transformer radiators recently had cause for satisfaction. They had completed the development of a new transformer radiator that gets along with two gaskets instead of four or six. A representative 100 000-kva transformer has 200 fewer gasketed joints.

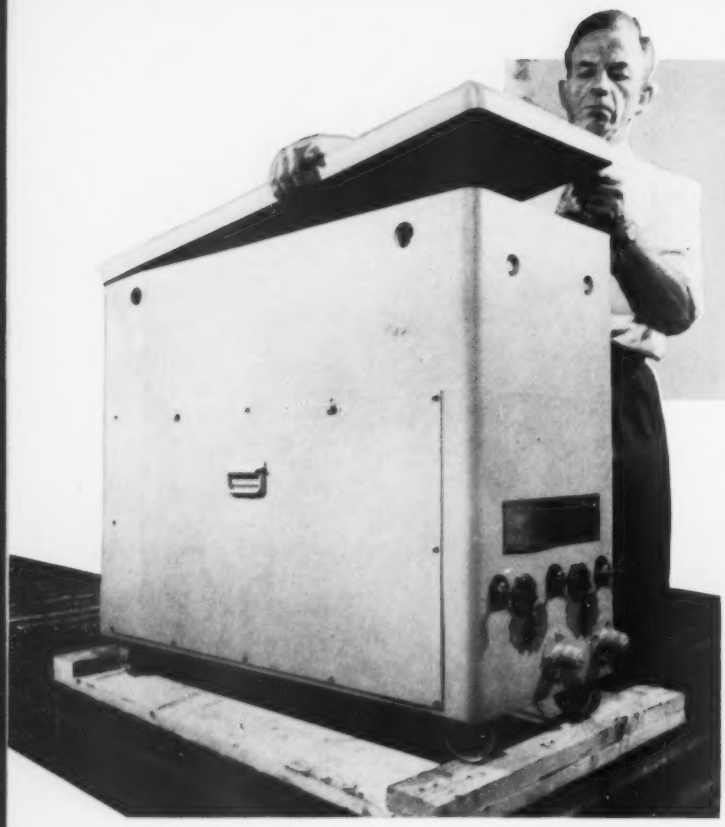


The primary object of the radiator development was to achieve a construction that would permit testing of radiators at higher pressure, and hence give greater assurance that leaks do not develop after long periods in service. The new radiator now easily withstands routine quality-control tests at 50 pounds pressure before mounting on the transformer. This is three times as high as before.

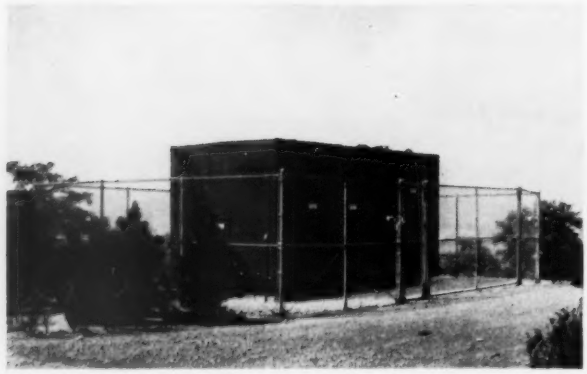
Better Looking CSP Power Transformers

THE SINGLE-CIRCUIT substation (CSP power transformer) has been improved in appearance—which is important in residential areas—and made so safe electrically against accidental or mischievous contact that the fence can be omitted if desired. The unit now has a 22-kv, air-insulated, load-break switch coordinated in design and physical arrangement with the transformer compartment.

Other CSP power transformers have been improved in appearance by better shaping the roof to give an overhanging edge, and by providing fewer but full-length doors. To assist in closing these long doors a latch mechanism guides the door top and bottom over the last two inches of travel. The result is an important transformer element that is simpler and better from a maintenance standpoint.



Oil-filter presses have been useful devices, but little thought has been given to their appearance. They have consisted of a steel skeleton on wheels with the components —including much plumbing—fastened to the frame and on shelves. The new one is enclosed in neat steel panels. Several mechanical improvements have been included, such as an automatic, float-operated valve on the sump that collects oil squeezed out of the edges of the filter papers.



A 2000-kva CSP power transformer with a 22-kv air switch.

Relaying and Line

Electrical Relays Have New Functions

THE RELAY front is marked by successful moves toward simplification. The three-zone distance-type relay (HZM) used for transmission-line phase protection, for example, is now fully self-contained. The auxiliary components, used to offset the impedance element of the relay, are no longer mounted in separate boxes, but are contained with the relay itself. Because it is now one unit, it can be mounted in a Flexitest case so the relay can be removed from the panel for inspection or test. Consolidation also means less inner wiring and less switchboard wiring. The new relay case is only one inch deeper than the previous one.

Loss-of-Field Protection—If a large synchronous machine loses the direct-current supply to its field, or is even inadequately excited, it can be seriously damaged. With machines becoming so large, such mishaps can be costly. Also, with power systems growing larger and more complex, it is increasingly important that stability not be jeopardized by one machine losing its excitation.

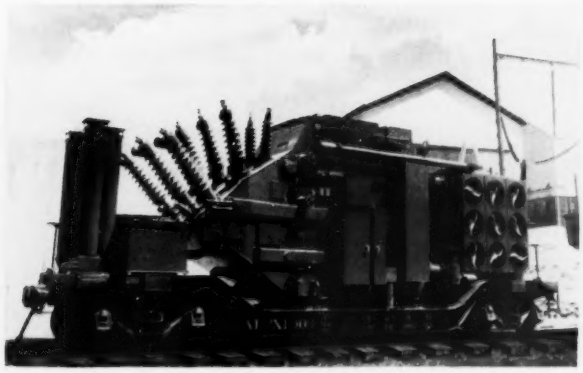
A new loss-of-excitation relay (HLF) provides a higher order of protection than has been available before. Momentary loss of excitation—for two or three minutes—is not hazardous to a steam-turbine generator, and the excitation can be safely restored gradually even if the machine has lost synchronism. However, momentary loss of excitation might be hazardous to the system if system voltage drops too low.

By taking advantage of these facts, a new relay has been designed to meet three situations. If a turbine generator loses excitation and a dangerously low system voltage results, the machine is automatically tripped off the line. If the loss of excitation is not hazardous to the system, the relay warns the operator of the situation, allowing him to correct the trouble if possible, thus saving an unnecessary outage. In addition, if the excitation of the machine becomes abnormally low for any reason, and dangerous heating or loss of steady-state stability might result, the relay warns the operator of this condition although the excitation system is intact. In short, the relay analyzes the situation and either takes proper action itself or informs the operator of the corrective action necessary.

The relay is a single-phase device consisting of an offset-impedance element, a directional element, and a voltage element. The impedance and directional elements combine to determine the presence of dangerously low or zero excitation, and the voltage element determines whether system stability is endangered. This type of protection against loss of excitation is applicable to all classes of synchronous machines—turbine and waterwheel generators, synchronous motors and synchronous condensers.

Synchronous-Machine Rotor Protection—The new industry standards call for a means of protecting the rotors of large synchronous machines from overheating on line faults. The standards define the capability of synchronous machines to withstand negative-sequence currents resulting from external faults in terms of the negative-sequence current and time. Negative-sequence currents in a machine cause dan-

This 50 000-kva mobile transformer is now in service on the American Gas & Electric system. It can be used to interconnect a 132-kv system with either an 88- or a 66-kv system and can step down from 132, 88, or 66 kv to 44, 33, or 22 kv. It is a three-phase unit and is moved from place to place, filled with oil and with its coolers and bushings in place. When in transit only the arresters have to be removed. This 50 000-kva unit is contained in the same dimensions and weight that would have been required for a 17 000-kva rail-car-mounted unit ten years ago. This is made possible by using forced-oil, forced-air cooling with directed flow, and Hipersil steel, by simplifying the number of connections as much as possible, by turning the core-and-coil assembly on its side to save height.



Communication

gerous currents to flow in the wedges and retaining rings of the rotor. The result can be excessive heating of these parts.

The new COQ relay is of the induction-disc type and closes its contacts if the summation of the current squared and time exceeds a predetermined value. A negative-sequence filter, consisting of a mutual reactor and a resistor, is used with this relay. The COQ relay matches the generator thermal-capability curve and permits operation to a point just below that where the possibility of machine damage arises, giving a maximum margin for coordination with other relays with a minimum of application effort.

A new relay (CA5) provides current protection with variable percentage characteristics for transformers and generators.

A field team measures carrier-frequency attenuation.

Transmission Lines Measured for Power-Line Carrier

TO MAKE SUCCESSFUL and well-engineered applications of power-line-carrier equipment, designers generally need certain information that just plain isn't available. The equipment should be adequate for the service desired but at the same time no more elaborate than necessary. Thus, engineers should know the characteristics of that particular line at the frequencies employed by the carrier with special reference to the carrier-frequency influence voltages.

This information is hard to come by. To calculate it with any degree of accuracy is hopeless. There are simply too many variables associated with a particular system to make this possible. Just the existence of several stub feeders, with their many reflected waves, makes close calculation extremely troublesome. Line voltage, kind of construction, and length of various circuits are the principal factors. However, many other things have lesser bearing on characteristics of high-frequency signals, such as: sag in the line, kind of insulators, type of terrain, ground resistance—even attenuation of a line is different in summer with tall corn growing below it than in winter with the ground bare and dry.

To bring order out of this situation, survey parties spent several weeks in each of the last two summers measuring the characteristics of actual lines. When it was known that a high-voltage line was to be de-energized, this crew with wide-band signal generators and signal-strength measuring meters would move in and collect data. By this method a mass of data is being collected on enough lines of different voltage, constructions, and other conditions that power-line carrier applications can be made with greater dependability.

Microwave at Work

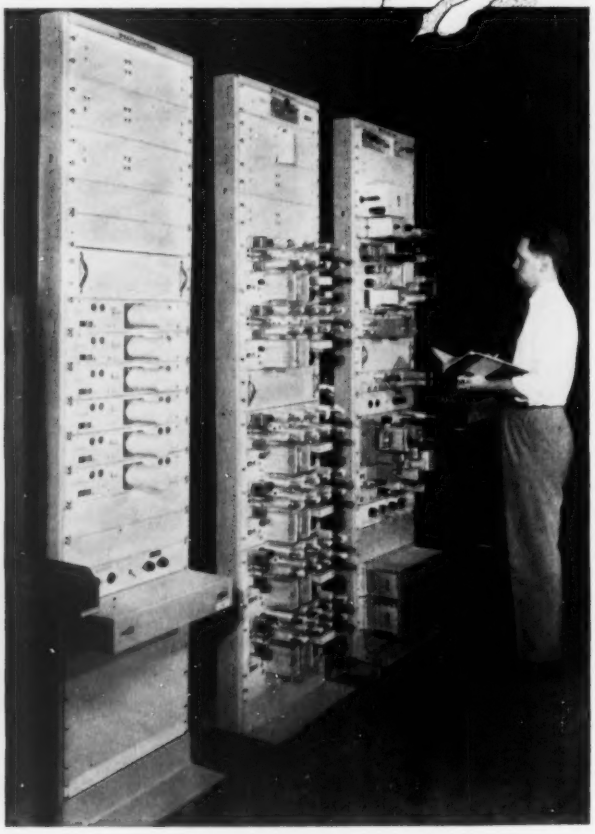
MICROWAVE INSTALLATIONS are now being made in significant numbers. Much progress has been made since the first installation was placed in operation in February, 1949. Several installations of the 960-megacycle equipment are now in operation, providing reliable relaying, supervisory, telemetering, and communication services. Delivery of the new, higher capacity 2000-megacycle equipment was started in 1953. Of particular interest is a two-station system being installed by Tennessee Valley Authority. This will have a total of 30 voice channels, the largest number ever included in a single industrial microwave system. In addition, it is expected that several of these voice channels will be further submultiplexed by audio-tone equipment to provide telegraphic functions, such as telemetering and supervisory-control channels.

Of particular moment is the installation of microwave equipment for remote control and telemetering of two unattended booster stations on the system of the Plantation Pipe Line Company. It consists of seven microwave stations, each equipped with operating and standby microwave equipment, all interconnected as a complete system to supply one party-line voice circuit available at each station; and 12 telegraph channels for supervisory control and telemetering. Antennas for very high frequency transmission are installed for future tie-in with mobile radio used in maintenance. Teletype or other service channels can be added.

The 2000-mc microwave apparatus (type FR) has several interesting technical features. One is its capacity to provide as many as 30 voice channels. Another is a means for automatically cutting in standby equipment at either a repeater or a terminal, upon failure of transmitter output or received signals. This automatic-transfer device can be installed in space available in a standard size microwave cabinet assembly. Also, an automatic alarm system gives a remote indication of up to six functions and the station identification where these functions have taken place. These indications are displayed visually at an attended station in a microwave system and permit the operator to assess the difficulty and to take corrective action. Examples of functions that this alarm equipment can be used to indicate are failure of tower lights, transfer to standby microwave radio equipment, transfer to emergency power, or unauthorized entry into an unattended station. This alarm system includes a memory circuit that stores information on troubles at one station until troubles being reported by another station have been transmitted. This alarm system utilizes the signaling tone for the service channel on the microwave equipment and thus does not deny normal use of any of the 30 channels available for operational use.

The several hundred people at the Knob Lake, Labrador, site of the new iron-ore development will depend for telephone communication on power-line carrier. It will operate over the wire signal circuit paralleling the 360-mile ore road. It will provide 11 voice channels, 6 for duplex teletype—heavy loading. Below are panels containing apparatus for teletype, telegraph, and single-sideband communications, respectively.

Microwave equipment in a station of the Plantation Pipe Line Co.



Single Phase and Three Phase from One Transformer

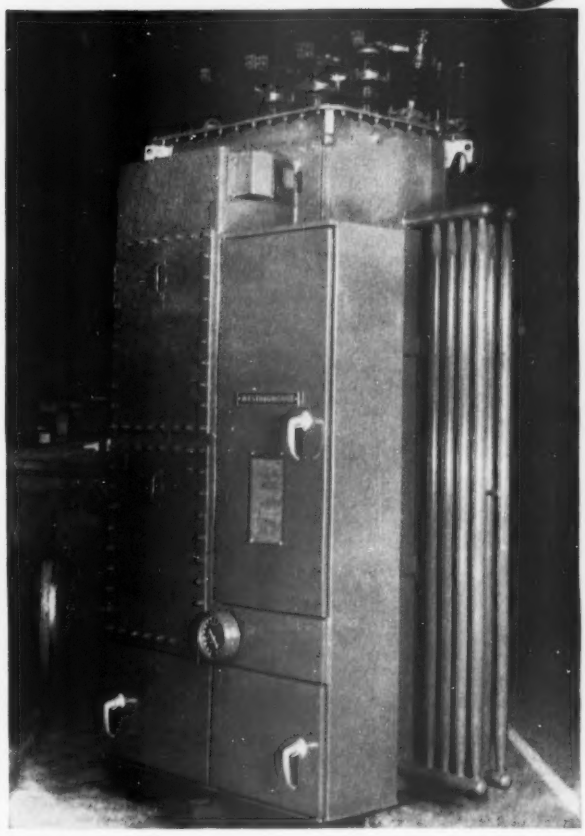
WITH THE RISING popularity of air conditioning, power companies are finding need in many of their residential areas to supply some three-phase power in addition to single phase. One way of doing this economically is from a distribution transformer with two dissimilar windings in one tank. CSP duplex transformers are now being made for this purpose. They can be built for different combinations of ratings, but a common one is 25 kva, single phase, and 5 kva, single phase, which can be connected in open delta to supply 8.66 kva, 3 phase, and 25 kva, single phase, or any limited combinations of these. The windings are different in size, in keeping with the different load requirements, and are arranged for open-star primary connection and open-delta secondary. In the three-phase bimetal-actuated breaker that became available about a year ago, fortunately the bimetals can be connected in the two windings so as to give full protection for both single-phase and three-phase loads.

Distribution Devices

Transformer Arrester Handles Heavier Fault Currents

A NEW LIGHTNING ARRESTER for distribution transformers has much higher 60-cycle current capacity to handle the heavier fault currents of the fast-growing distribution systems of today and tomorrow. This arrester (the LX-T) is an adaptation of an expulsion-type arrester originally created for crossarm mounting. It has been modified to make it suitable for mounting on a transformer tank. In this arrester the occasional power follow or 60-cycle current is forced to travel the long path of a spiral groove in a fiber tube, creating thereby a large amount of gas that snuffs out the arc. This lengthening of the arc produces a high arc voltage that is effective in greatly limiting the magnitude of power-follow current. It has been tested with consistent success on 3-kv circuits capable of developing 21 000 amperes. The new arrester is about the size (and much the same shape) of a pint thermos bottle. Tests indicate the life of the fiber tube and core is adequate for more than 35 years' normal service.

Top to bottom: A duplex transformer; a distribution-transformer arrester; and a step-type voltage regulator.



Simpler Adjustments for Voltage-Regulating Relays

ADJUSTMENTS on the voltage-regulating relay are much simpler—and the results are much more accurate—if they can be made by turning similar knobs than if the operator has to move a weight for one adjustment, set a magnet for another, turn knobs for a third, and finally change a set of links. The new primary relay—the gadget that provides the intelligence for a load tap changer—is built on this basis. Setting voltage level, bandwidth, adjusting the resistance and reactance compensation, and reversal of the reactance element where desired are all done by turning knobs in front of dials. The new relay also retains the drawout feature, with a quick-

connecting plug so it can be removed for inspection away from the regulator. The overload capacity of the compensating element has been enlarged, and conforms with the new industry standards. The relay is mounted on rubber to prevent vibration over a long period from damaging any of the elements. An armature-bearing clamp, operable from outside the case, has been added for use during shipment or handling in service to prevent shock damage to the hinge spring.

Low-Voltage Distribution and Control Devices

Direct-Current Operated A-C Contactors—Small contactors, such as NEMA size 1, are predominantly used as a-c devices. For a few applications it is desirable to have them operate from battery-powered or other d-c control circuits. To put a d-c coil on the a-c magnet structure is possible but does involve high operating temperatures because of lack of winding space. To simplify the construction and to make the a-c contactor (type N) more reliable when used with d-c control, new magnet mechanisms designed especially for d-c use have been developed.

Motor-operated breakers now won't "freeze up" in cold weather. By the use of the new lithium-type grease for the switch bearings, gear case, and motor—and sealed for the life of the apparatus—the device can function at temperatures as low as −65 degrees F or as high as 175 degrees F.

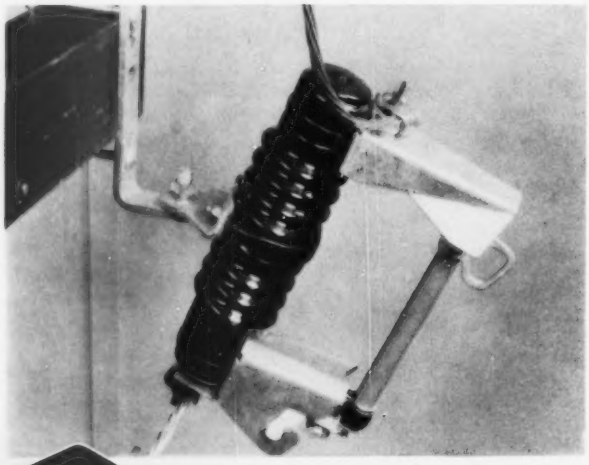
The *cut-off switch* for motor-operated breakers has been redesigned to strengthen operating parts and thus reduce maintenance. The switch is not damaged if the drive mechanism is inadvertently turned manually in the reverse direction.

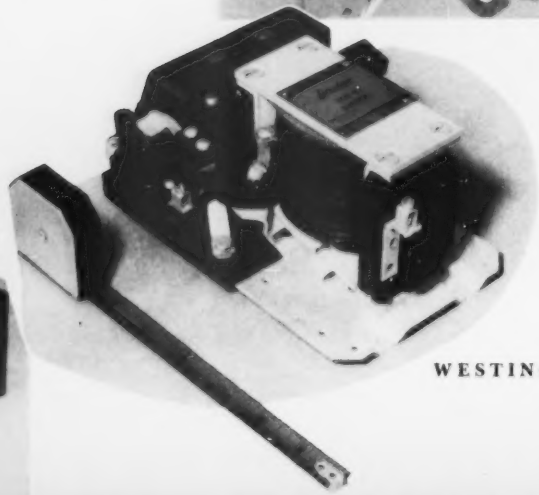
Temperature-Compensated Circuit Breakers—In an irrigation project, say, the control panel may be mounted on a pole exposed to the sun, while the motor may be in the relatively cool shade of an enclosure. In this case the breaker may overprotect, because of its own high ambient temperature, and shut the motor down unnecessarily.

To take care of situations where ambient temperature may be a problem, the 100-ampere, molded-case breakers can be provided with two bimetals, one functioning to trip the breaker on overcurrent, the other automatically adjusting for ambient temperature. This eliminates unnecessary tripping operations.

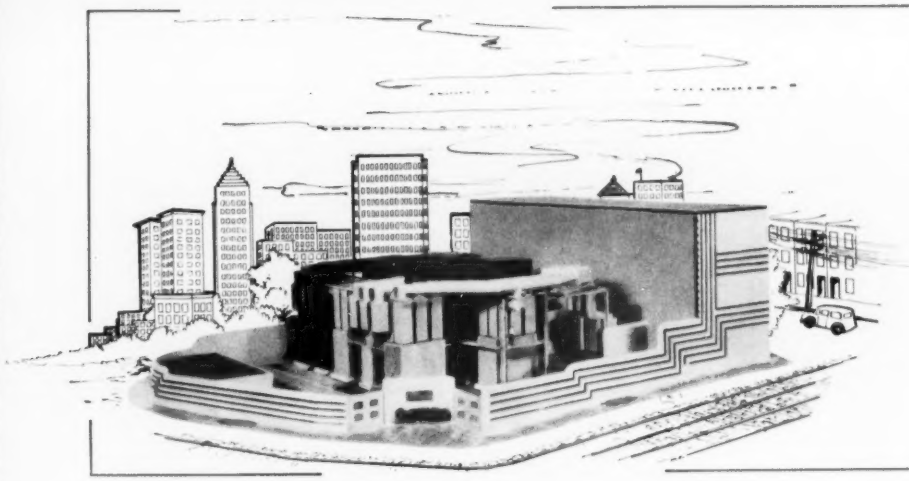
Cushion Starters—The new step-type starter reduces yarn breakage on textile spinning frames. Yarn breakage due to jerky starts of the spinning frame has been exasperating to textile men because it lowers production rates and impairs quality. With the new control the frame motor is first connected on only half the winding, greatly reducing starting torque. A second contactor cuts in the other half of the winding in three steps, each providing more starting torque. A smooth, slow start is obtained regardless of the drive ratio between motor and frame and regardless of load friction conditions at the moment. The cushion starter takes care of the starting sequence automatically. The spinning-frame operator has only to push a start button.

A new cutout (type DX) accomplishes several things. It is more rugged, simpler than its predecessor, has no more contact area, and employs sleet shields on top and bottom contacts—but, most intriguing, it is "bird-proof." A bird can give himself a hot seat by sitting on one live or grounded part and pecking at another. However, a polyethylene coating on the metal clamps that hold the unit to the porcelain insulator eliminates short circuits of either natural or bird origin. The new cutout will protect bird life from 5.2, 7.8, and 15 kv, and interrupt 3000 amperes for the two lower ratings and 2000 amperes for the 15-kv rating. A heavy-duty cutout is available to handle about twice these current ratings.





Far left: A motor-operated disconnecting switch suitable for operating over a wide range of ambient temperatures. *Left:* A new type of relay is designed for operation of an a-c contactor from a d-c power supply.



Model of a 69-kv metal-enclosed substation under way for the Duquesne Light Company. Because this substation is being built in a highly congested area, safety, good appearance, and compactness are paramount qualifications. Full impulse strength is also a requirement. In order to determine the adequacy of the design of the air switches and isolated phase bus, one prototype unit was built and subjected to about 1000 impulse tests before satisfactory design was obtained that would meet the very limited space available.

Adjustable Bus Duct

STANDARD BUS DUCT is made in nine lengths from two to ten feet long. A combination can be picked to span a factory space of 23 feet. Or for 24 feet. But how about 24 feet 3½ inches? Until now such situation has called for a specially made section to manage that 3½ inches. But this is no longer necessary. A new telescopic plug-in bus section can be made as short as four feet or as long as five feet, or any length in between. A series of holes in the overlapping bus and in the housing is such that matching bolt holes can be found for any position over a one-foot range. The housing has a telescoping arrangement to cover the same range.

Better, Simpler Wiring Devices

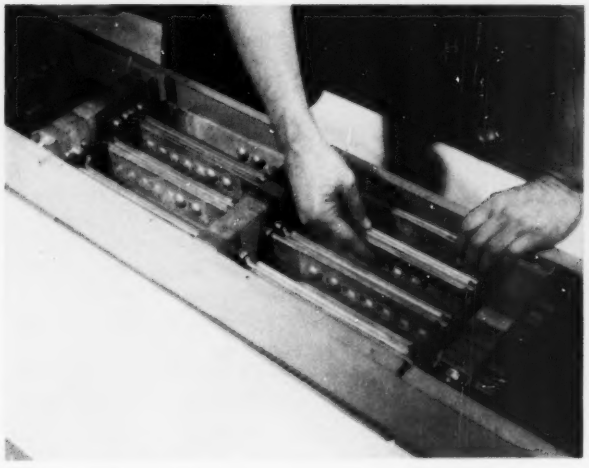
LIKE A KITE with too much tail, wall switches for a-c circuits have always labored under a handicap. The design of the switch has been compromised severely by the fact that the switch must serve both d-c and a-c circuits. This has been tradition since the origins of the industry. Time was when this was a good idea. But that day passed some time ago.

The most favorable designs for d-c and a-c switches are quite opposite. Direct current is interrupted by stretching the arc so far it can no longer sustain itself. This specifies fast-acting, widely separating contacts. Alternating current, however, inherently goes out once every half cycle. It is desirable to separate the contacts slowly and not very far so that at some early half cycle the arc simply does not restrike.

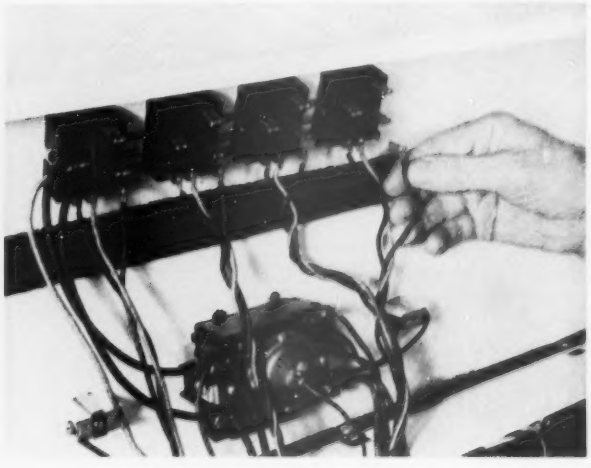
In accordance with the recent decision of the Underwriters' Laboratories and the Wiring Device Industry not to require a wall switch to serve both currents, Westinghouse has developed an a-c switch to capitalize on the advantages of the singleness of purpose. These are several. For one thing the switch is quiet because the snap action is no longer needed; in fact, it is undesirable. Also a single a-c switch is good for the following larger variety of services: for tungsten-filament lamp loads up to the current rating of the switch; an inductive load (such as fluorescent-lamp ballasts) up to the rated current of the switch; and motor loads in which the full-load current is not more than 80 percent of the current rating of the switch. (The old d-c, a-c switch could not do all of these things.) A further advantage is that the switch is good for 277-volt lighting circuits.

A More Conveniently Wired Convenience Outlet—Visualize the time-honored method of attaching conductors to the ordinary convenience outlet. It is welcome news to home-owners,

This bus duct is adjustable to any length from four to five feet.



A Bryant electric-range switch is connected without screws.



tenants, contractors, and electricians that the long-used method is now out of date.

The new Bryant convenience outlet does not employ wire binding screws. Instead, the wire is held firmly in electrical contact by a spring clamp. To make a connection, insulation is stripped from the end of the circuit wire, and the bared end is inserted in a small opening in the rear of the receptacle.

Stouter Induction Regulators

SINGLE-PHASE INDUCTION voltage regulators are inevitably exposed to a continuous 120-cycle pulsating torque and to occasional high short-circuit stresses. A new family of regulators is better able to stand such rigors. Rotor and stator are designed to have the same natural torsional period to equalize the 120-cycle deflections. By proper choice of the top support for the rotor, these deflections cancel each other. As a consequence, the motor and other auxiliaries mounted above the stator and rotor experience essentially no vibration. The whole unit becomes more shock resistant.

The family of regulators, which covers the range of sizes from 37½ through 125 kva, has also been improved otherwise. The relays have been placed on the rear of the swinging panel where they are easier to get at. The motor drives through a double-worm gear instead of a single worm and gear, which is quieter and better able to resist short-circuit forces. Rotor and stator windings have been redesigned to capitalize on several years' improvements in insulations. The regulators, thereby, are smaller than before.

New induction regulators have been made mechanically stronger.

Larger Sectionalizer for Urban and Suburban Service

A new 140-ampere sectionalizer extends the use of the device to high-capacity feeder circuits, and makes it more adaptable for use with reclosing circuit breakers and large oil reclosers. The sectionalizer is a series-connected device that counts pulses of fault current created by opening and closing of the automatic circuit breaker, and isolates the feeder line after a preset number of counts. The principal innovation on the larger capacity sectionalizer is the series trip coil, which is able to withstand 5 × 10-microsecond surge currents as high as 65 000 amperes. The coil is formed of edge-wound bare copper, to give maximum heat dissipation, and turns are rigidly braced to withstand high current surges. The new sectionalizer, like its companions of lesser rating, is oil filled and can be safely used to break load currents up to 220 amperes. The device can operate 2000 to 5000 times without maintenance if necessary. The type GRS sectionalizer has been applied on distribution circuits up to 13 200 volts.

Big Year for Capacitors

WHEN THE HISTORY of electrical power apparatus is drawn up some decades from now, it is likely to record that 1953 was an all-time banner year for capacitors. The number of improvements in capacitors themselves is unusual, but of particular note are the new ways they can be used. All this coming after 25 years' development—and with a fundamentally simple device—is a testimony to technical skill and imagination of capacitor designers.

Large, high-voltage banks of shunt capacitors have customarily consisted of many capacitor units arranged on decks of a steel framework, built up on the site. It resembles the steel skeleton of a two- or three-floor building. Such construction in-

volves expense, much field work, and the services of unions skilled in that type of erection.

Field work of that type is no longer required. The development of the stacked capacitor makes it unnecessary. This is a factory assembly of 24 of the 25-kvar capacitors in a strong iron frame or cage. This becomes a 600-kvar unit that can be stacked as many as four high on a set of porcelain insulators, making a bank of 2400 kvar in an area of 3½ by 9 feet. As many of these four-high stacks can be placed side by side and connected electrically as the situation calls for. Erection calls for the simplest of concrete-pad foundations, and for assembly tools nothing more complicated than a wrench. Thus, it becomes possible to erect a high-voltage capacitor bank for about the same cost per kvar as low-voltage, pole-mounted units. Should system conditions change, the stacks can be unbolted and moved, or added to with no fuss.

High-Voltage, Metal-Clad Capacitors—In the crowded spaces of a city it is virtually impossible to build a high-voltage capacitor bank that is proof against small boys throwing things over the fence into the high-voltage lines, or other hazardous activities of miscreants. To seal up the capacitors has been considered too expensive.

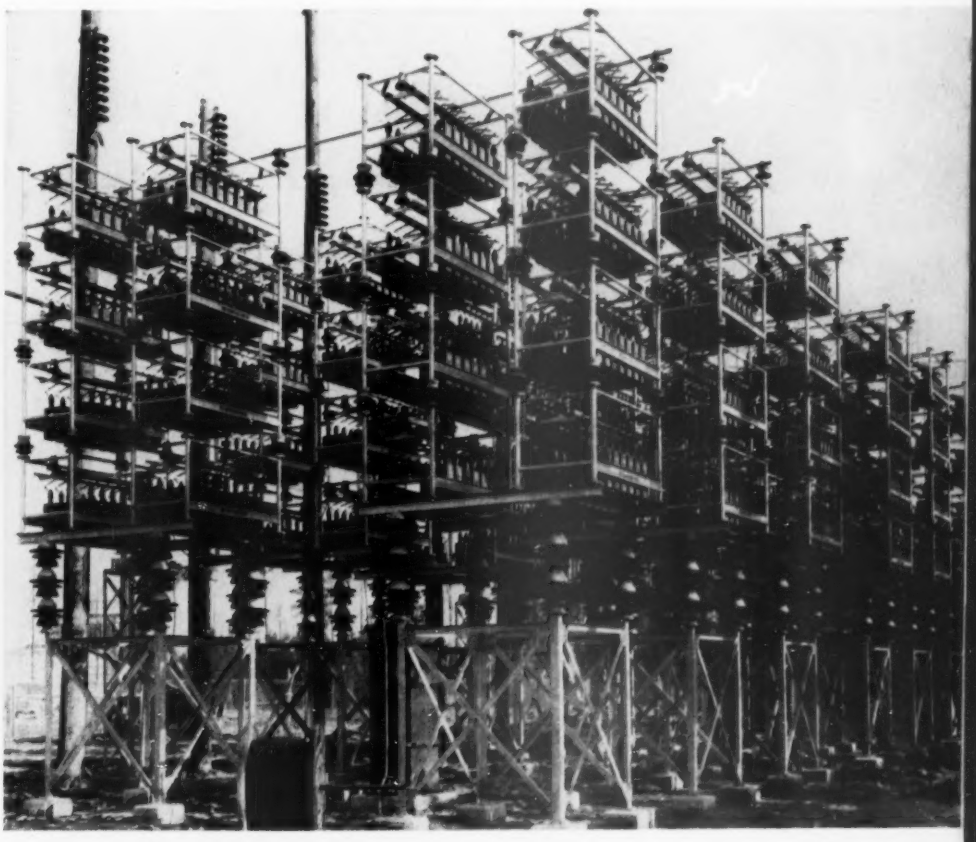
A new design, following metal-clad switchgear experience, has provided an enclosure without prohibitive cost. The scheme is to mount the new 25-kvar unit, with forced-air cooling, in metal-clad cubicles. A 10 800-kvar bank in Indiana was recently made that way. It was shipped in only eight housing sections—thus cutting down on erection labor.

Dust-Tight Capacitors—Then there is the matter of operating high-voltage capacitors in dusty locations. Heretofore this has not been done for voltages above 575. Now units of 120-kvar, 3-phase, for voltages of 2400 or 4160 volts are specially designed for precisely this duty. They are natural-draft air-cooled, and contained in rectangular metal cases 52½ inches by 32⅝ inches by 24 inches high, and can be stacked three high if need be. The units contain all necessary fuses, terminals, and knock-outs for electrical interconnection. The capacitors are turned on their side, for maximum cooling.

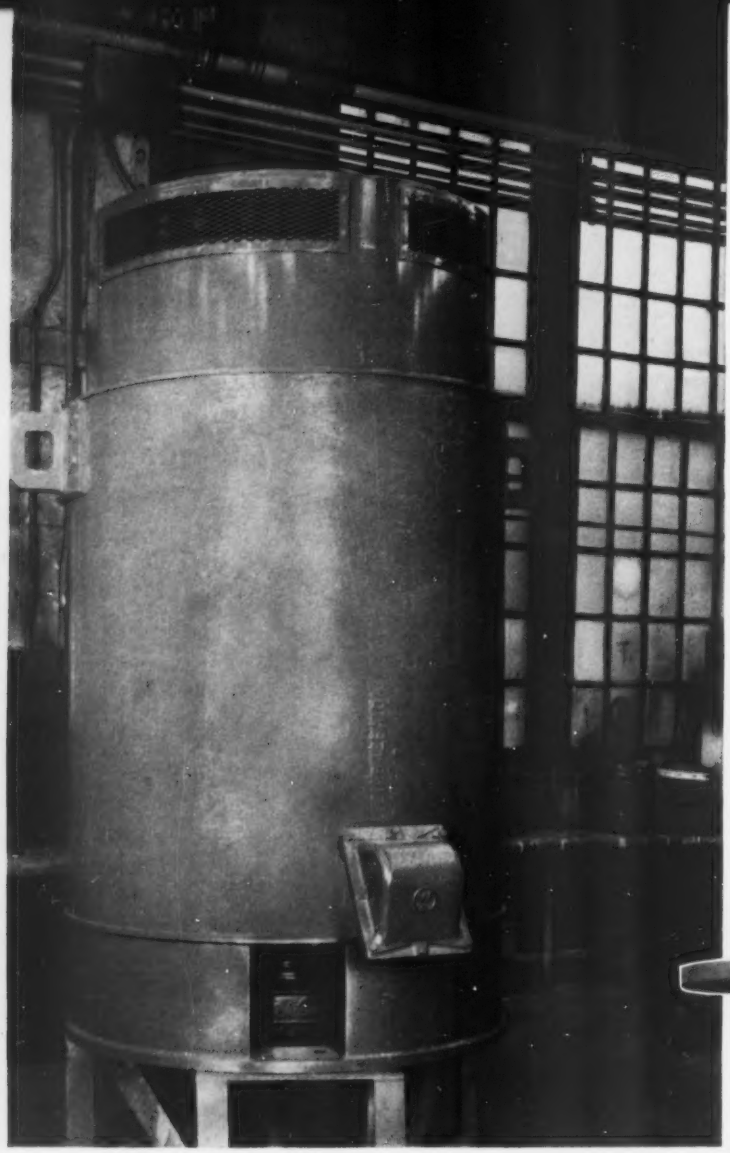
Network Capacitors—One of the many enlarging eddies in the electrical-equipment stream caused by air conditioning is the need for capacitors for network application that can be mounted in vaults susceptible to flooding. For this growing need, capacitor engineers have carved out an array of units. Use is made of a new 15-kvar, 230-volt unit, twice the kilovar capacity previously available at this voltage. A new insulating paper, only 0.000 25 inch thick and of reliable quality, is largely responsible. Also a whole new capacitor design has been necessary because at this low voltage the current is large, the current-carrying parts become a design factor, and I^2R something to consider. By a nice coincidence the 15-kvar, 230-volt capacitor has a rating of 13⅓ kvar on network voltage (216). Three units have a rating of 40 kvar; six units, 80 kvar; and nine units, 120 kvar, which match closely the ratings necessary for the standard network transformers of 300, 500, and 750 kva, respectively. The units employ the zinc-sprayed cases and solder-seal bushings, which make immersion, even in salt water, meaningless. A synthetic-rubber cap encloses the metal portions of the terminals. Within it and directly connected to the terminal is a current-limiting fuse that isolates the capacitor should an internal short-circuit occur. Network capacitors are arranged to fit in manholes, or mounted on walls, placed upright on the wall, side mounted on the floor, or stacked.

Pole-Mounted, Three-Kvar Capacitors—Household air conditioning is on the increase too. To keep a decent power factor, some correction is necessary near each house, or at least in each block. The need obviously is for a capacitor that is inexpensive, is small, and can be easily mounted in any one of several positions on a pole. A new 240-volt, 3-kvar capacitor sealed in an aluminum cylinder about the size of a rolled-up Sunday paper is just that. It weighs only 15 pounds, just about half of other three-kvar units, has a mounting bracket like that used on arresters for fastening directly to a cross arm in any way that fits in with other apparatus. The cover is welded on to seal the unit permanently against moisture. A special terminal-mounted fuse clears the fault before the pressure forces open the weld or causes more serious damage.

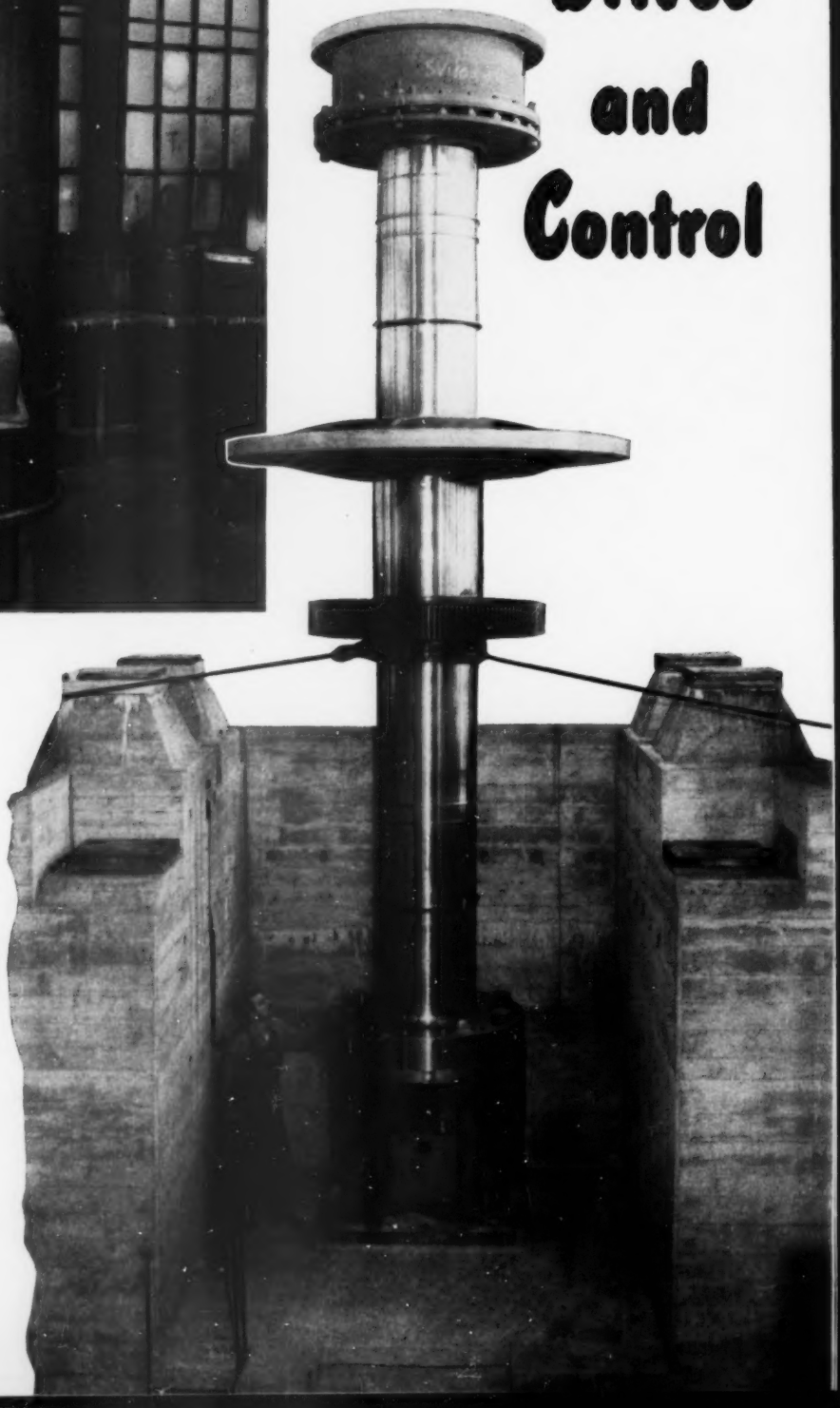
An outdoor bank of shunt capacitors is made by stacking self-contained, factory-assembled units.



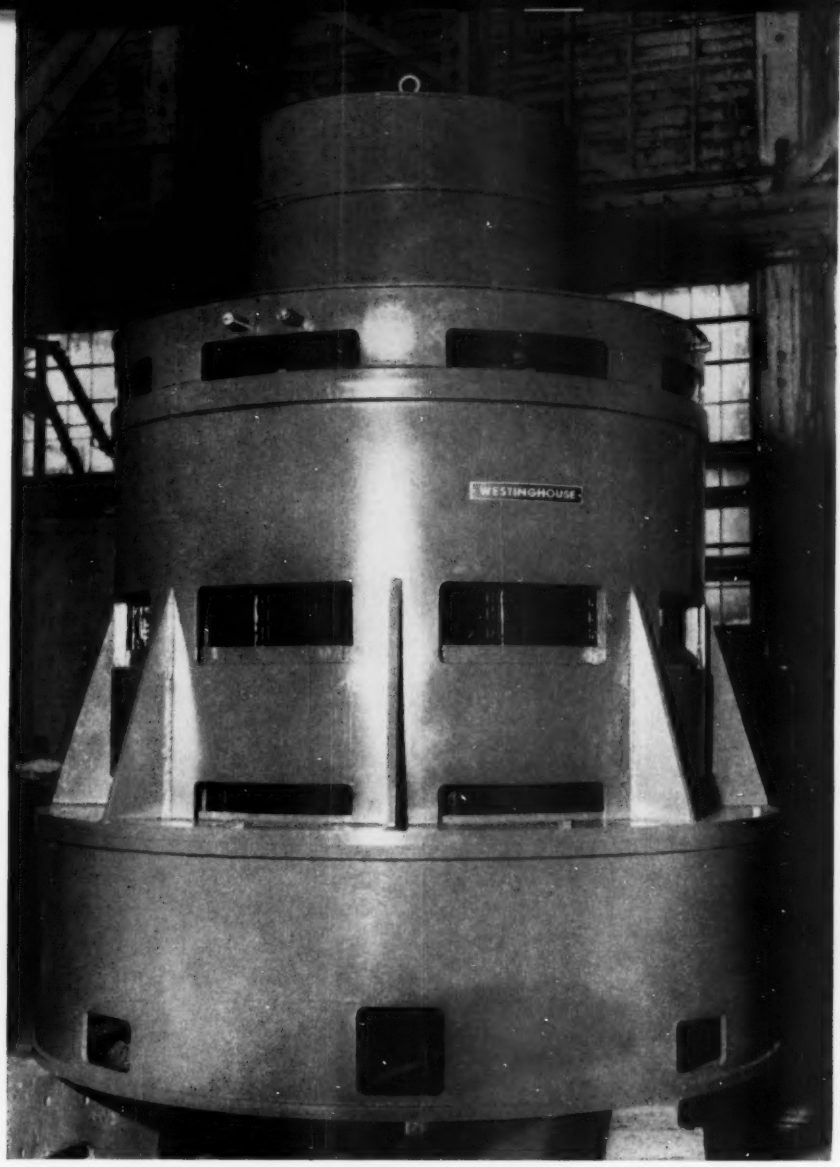
Drives and Control



A 250-hp, solid-shaft, explosionproof motor used to drive a vertical pump for combustible materials in a large oil refinery.



The shaft for connecting the Tullahoma wind-tunnel motors to the transonic compressor here stands vertically in the rotor assembly pit. At the top is the coupling that bolts onto a similar coupling on the motor shaft. The large flange above the center is for the mechanical brake; below that is the bull gear for the turning gear. The flange at the bottom bolts to a 45-foot long hollow shaft that passes through the corner of the wind tunnel to the transonic compressor. The shaft weighs 99 250 pounds. It is 30 inches in diameter at the bearings and 65 inches in diameter over the coupling.



Vertical Flywheel Motor

A recent application for pumps demanded the highest order of reliability. The pumps must continue to run even through a momentary interruption of power. For this purpose twelve specially designed, vertical squirrel-cage induction motors were provided with built-in flywheels. Each motor is rated at 900 hp, 585 rpm and has a 7-foot-diameter flywheel with an energy storage of 4 260 000 pound-feet, which will maintain the pump above one-half speed for a 15-second power interruption. Large shoe-type bearings take the heavy downward thrust of rotor, flywheel, and load. Special heavy bracing of motor end windings is necessary to prevent distortion by the heavy currents during the long acceleration period.

Gargantuan Pieces for a Gargantuan Wind Tunnel

ORDINARILY the shaft of a rotating machine has little opportunity to make the headlines. But when it is 25 feet long, $2\frac{1}{2}$ feet in its smallest diameter and $5\frac{1}{2}$ at the coupling, and weighs 50 tons, it deserves special mention. Such is the shaft driving the wind-tunnel compressors being built at the Westinghouse plant in Sunnyvale, California for erection at the Arnold Engineering Development Center, Tullahoma, Tenn. The shaft carries the power from four driving motors, two of which are a fourth larger than the largest motors ever built. The shaft, for all its size, has been carefully balanced so that vibration measures less than 0.001 inch, and is so well floated on oil in its bearings that it can easily be turned with one hand acting on the periphery of the brake wheel. This shaft is shown on page 22.

The rotors for the five mammoth axial-flow compressors are mounted on a series of discs $17\frac{1}{2}$ feet in diameter, 5 inches thick at the rim, and $7\frac{3}{4}$ inches thick at the hub. These 21 discs were machined from the largest forgings that can be made in the United States. To meet rail clearances, they were shipped, tipped at an angle, in special cars that permitted these enormous discs to ride only six inches above the rails. The forgings originally weighed 71 000 pounds and were machined to 46 000 pounds.

Larger Explosionproof, High-Thrust Motors

AN OIL REFINERY is a quiet place, without apparent motion. The visitor sees nothing happening. But, within the maze of pipes and towers, fluids in great volume are on the move. Pumps in large number and variety provide, literally, the heart for the system. Many of these require vertical, high-thrust, driving motors similar to those developed originally for irrigation systems. For refineries and chemical-plant and other hazardous-area applications they must, in addition, be explosionproof.

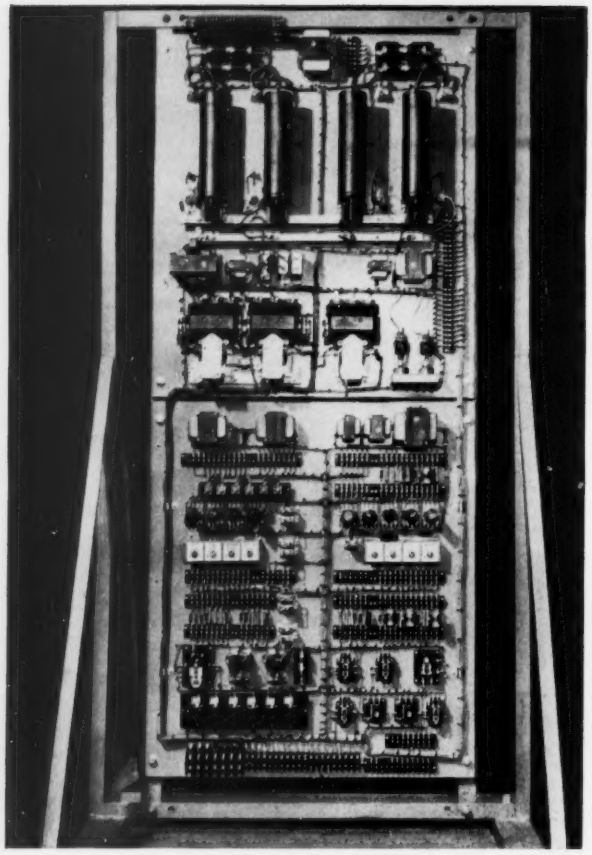
Last year saw several larger sizes added to the ratings of explosionproof, high-thrust, vertical motors. Available are 300-hp, 1780-rpm, hollow-shaft motors as well as solid-shaft motors rated 250 hp, 703 rpm, and 500 hp, 1200 rpm. Still larger motors can be built when they are needed.

A new application for the hollow-shaft motors has also appeared. This is for pumping aboard a seagoing chemical tanker. This tanker is built much like an oil tanker, with many compartments that can be filled with different cargoes of acids or other liquids. Atop each compartment is an explosionproof motor of 60 or 75 hp driving a stainless-steel impeller located at the bottom.

Induction Motors Are Smaller

THE INDUCTION MOTOR—the workhorse of industry—has again been made much smaller for a given horsepower. Although exact comparison of new and old dimensions is not possible for all ratings because some old frames have been omitted and some new ones added, in general the new ratings are about twice that of the old for a given mounting dimension—a remarkable reduction in size.

Magnetic amplifiers and selenium rectifiers come in many forms.



This wide-speed-range Mototrol panel has front-mounted elements.

This program of reduction in motor size applies to the integral horsepower sizes (at 1800 rpm the ratings are 1 through 30 hp). The smallest sizes, frames 182 and 184, having an outer diameter of about nine inches and rated 1, 1½, or 2 hp at 1800 rpm, will be in production in January 1954. Successively larger sizes will go into production at five-month intervals with the largest frames (324 and 326 having an outer diameter of about 16 inches and rated 25 and 30 hp at 1800 rpm) starting production in the fall of 1955.

These new motors have mounting dimensions recently established by the National Electrical Manufacturers Association. NEMA standards, first established in 1930, assure interchangeability of motors built by various manufacturers. They have been changed from time to time to permit utilization of advances in the art. This recent reduction in mounting dimensions, while of greater magnitude than any previous change, does not affect the standards for operating characteristics. Each motor will deliver the same torques, be capable of handling the previously established overloads, and have essentially the same input both at start and at rated load, as did that rating built to the old dimensions.

This substantial reduction in motor size is made possible by using many developments that have accumulated since the standards were last established. Improved designs employ more compact arrangements of components. Insulating materials of superior characteristics provide the required dielectric strength in less space. Electrical silicon steel, capable of carrying more flux with the same loss, is used.

A Hot-Rod Mototrol

MACHINE TOOLS are requiring drives with wider and wider ranges of speed. Last year a drive was provided capable of a speed range of 240 to 1. For certain cutting work, speeds as low as 7½ rpm are desired, yet always a high-speed return of the table is sought after each cut. While the normal cutting range lies between 7½ and 600 rpm, the drive is capable of holding any speed up to 1800 rpm relatively constant for all changes in load from zero to full torque.

Only a d-c motor with electronically supplied and controlled power such as the Mototrol can meet such extreme conditions. And the standard Mototrol cannot come close to fulfilling these requirements. However, by making the regulating circuits faster and by increasing the system gain some five times beyond normal, a Mototrol has been achieved that fully accomplishes the desired purpose.

Reference Devices for Electrical Controls

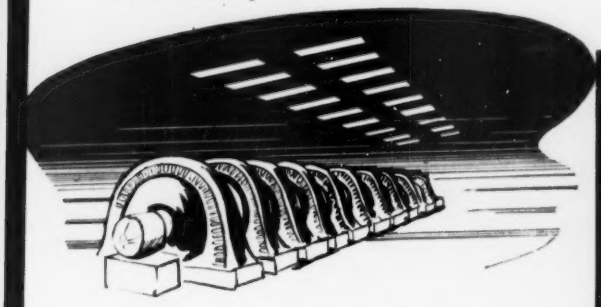
AS WHEN HUMANS make decisions, a control device must have a basis for judgment. In short, control devices must have a standard or reference. And this reference, in most cases, must be constant and unaffected by surrounding influences. For example, the reference for a magnetic amplifier controlling the output of an aircraft alternator must be steady in spite of changes in voltage and frequency of its

power supply and indifferent to wide swings in temperature. Other obvious requirements have to do with limitations of size, weight, and resistance to humidity, vibration, and mechanical shock.

A new constant-current reference for a regulator for narrow-speed-range aircraft alternators has been developed that is itself a magnetic amplifier. It is entirely a static device, made up of magnetic devices, dry-type rectifiers, and similar static components. Over a variation in supply voltage ± 20 percent, and in frequency from 360 to 440 cycles, the reference holds output constant within ± 0.25 percent. For any given condition of voltage and frequency, the regulator holds the output within ± 0.5 percent for temperature variation from −70 to +160 degrees F. The reference occupies a volume of about 24 cubic inches.

Keeping Reciprocating Machines Out of Step

THE PROBLEM of keeping a battery of reciprocating machines out of step to avoid shaking the place apart is an old one. Many attempts have been made to solve this problem but usually they are handicapped by complexity. A new one for compressors driven by synchronous motors is both novel and simple.



Each motor is equipped with an extra slip ring having a contact segment built into a small arc on its periphery. This slip ring turns under a pair of brushes, thus closing a circuit at just one point in each motor revolution. Common to all motors is a master reference, consisting of a brush rotated at motor synchronous speed around a stationary commutator having evenly spaced contact segments, one for each motor. One side of a circuit, common to all units, enters through the brush, and, in one revolution of the brush, makes brief contact with the stationary-contact segments at evenly spaced intervals.

An idle motor is started, brought up to speed, and synchronized in the usual fashion, but with weak field and with the compressor unloaded. A set of relays then begins to reverse the motor field excitation and, at each reversal, the motor slips a pole. This continues until the motor slip-ring contact closes in series with, and at exactly the same instant as that motor's indexing contact on the master reference. When this occurs, a high-speed relay closes to terminate the field reversing, to increase the field current to normal and to signal that the compressor can be loaded.

The master-reference brush rotates at the same synchronous speed as the compressor motors. Therefore, if the slip-ring contacts on ten motors are adjusted to close at approximately the same angular position in respect to their compressor cranks, and if the motors are synchronized with different angular points on the master-reference commutator, the compressor cranks are out of step with each other.

Gearmotor Rides the Roll

CHANGING GEARMOTORS on roll tables may soon be like changing razor blades—no fuss, no muss. A new version differs from the conventional flexibly coupled, rigidly mounted gearmotor in that the driving shaft on this new unit is equipped with a sleeve section that permits direct mounting of the complete gearmotor assembly on the roll shaft extension and thus is free to follow any eccentricity of the roll. Thus coupling and bearing failure due to eccentricity are eliminated. Time spent on coupling alignments is eliminated, and "down time" of rolls during gearmotor servicing periods can be reduced.

A new gearmotor for steel-mill run-out tables is mounted vertically and is overhung from the driven roll. Makes a change easy.

The gearmotor is provided with a torque rod to anchor the drive and prevent its turning, so that the whole drive "rides" with the roll. The torque rod is spring mounted for protection against severe shock loads caused by frequent reversals and possible roll distortion.

Space normally required for motor and coupling connections is saved by using the hollow-shaft mounting and turning the motor vertically downward. This design may result in savings of approximately 18 inches of aisle space per unit.

More Molded-Case Disconnecting Switches

A LITTLE OVER a year ago a new type of low-voltage disconnecting switch was provided by a fairly simple modification of the molded-case (AB) circuit breaker. This consisted mostly of removal of the overload tripping mechanism and omitting the cover to make the contacts visible. This development met with considerable success because it provides a disconnecting switch in an insulated case embodying the features of the molded-case breaker frame, and one that matches and coordinates well with molded-case breakers. This development has recently been extended to more ratings. Now four sizes are available: 30, 60, 100, and 200 amperes continuous, at 600 volts, 60 cycles. Each size is rated in horsepower and is approved by the Underwriters.

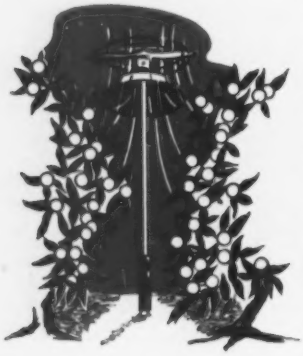
Stopping A-C Motors with D-C

IN MANY TEXTILE, machine-tool, and other plants it is desirable to have a machine stop quickly—instantly. This may be to protect the machine, or product, or the operator—or simply to save process time. There are mechanical brakes, of course, but they have well-known disadvantages.

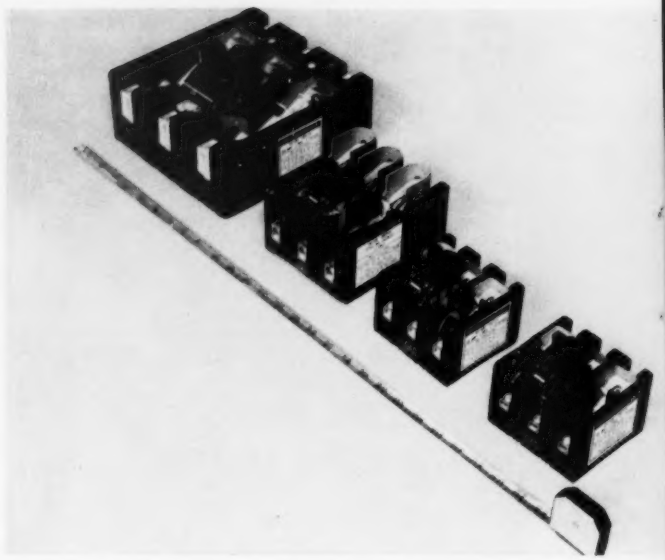
One way to stop an induction motor speedily is to apply direct current to one phase winding simultaneously with the opening of the three-phase supply circuit. The motor stops but quick. Unlike stopping by plugging, i.e., reversal of two a-c lines, there is no tendency for the motor to turn in the reverse direction after it has stopped.

A new starter incorporates all the devices for d-c braking. This includes the usual starting contactor, autotransformer, a timing relay, a full-wave selenium rectifier to provide the d-c, and braking contactor. The timing device removes the d-c after the motor has stopped. Taps on the autotransformer permit adjustment of voltage to the rectifier, thereby providing control of braking rate.

Frost Stay 'Way from My Orchard



An interesting new defense is being tried in the never-ending battle by fruit growers against frost. A vertical-shaft propeller-type fan, on a tower, moves a large volume of air downward against deflectors that drive it in all directions over the treetops. A 25-hp, 1180-rpm vertical motor is mounted on a steel tower and drives the propeller directly through a shaft extension at the top. One such breeze-maker is estimated to protect about five acres against light frost.



A line-up of 30-, 60-, 100-, and 200-ampere disconnect switches.

A Case Example of Magnetic-Amplifier Control

THE VERSATILITY of magnetic amplifiers is illustrated by an unusual control problem they were recently given to solve. In the operation of a certain machine, six independent lamps light in random sequence, each indicating that a specific action has occurred. It is desired that a master signal lamp come on after all six lamps have lighted, regardless of their sequence, and remain on until all six are extinguished.

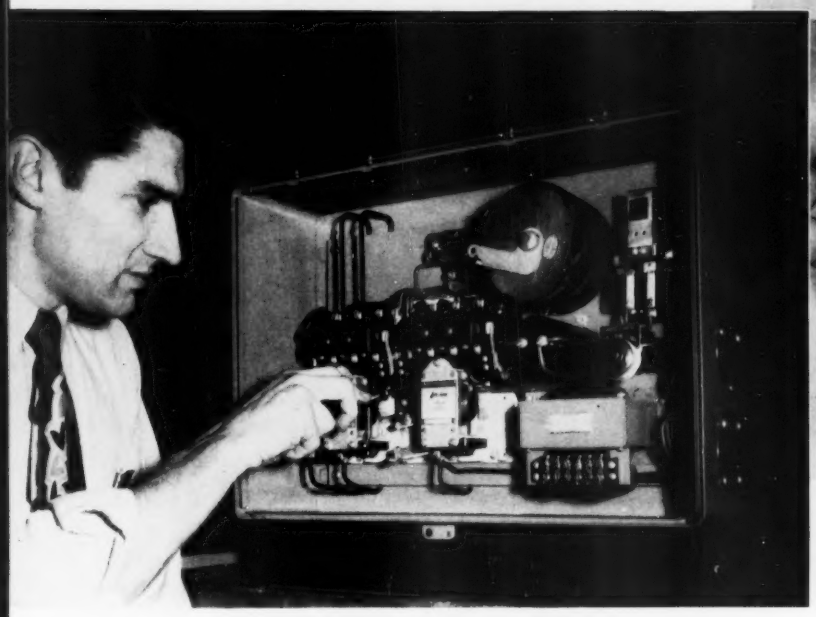
Systems to integrate currents proved cumbersome. To do it with interlock relays would have required 19 relays, because of the random operation of the lamps. However, it was a fairly simple matter to devise a magnetic-amplifier circuit that gives a signal only after all lamps light and another after they all are extinguished. Furthermore the system is independent of the number of lamps or elements in the system controlled. The completed control unit weighs about three pounds and is contained in a case about one fourth the size of a shoe box.

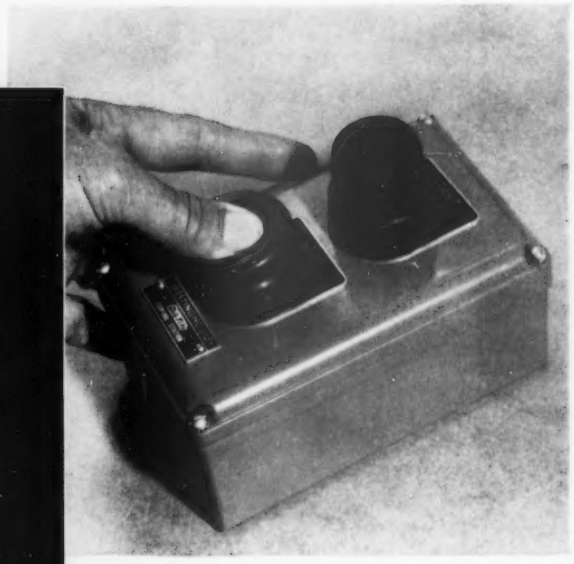
Regulators for the Giant of Wind Tunnels

MENTION of any aspect of the transonic and supersonic Tullahoma wind tunnels with their 216 000 hp in driving motors calls for superlatives. Regulators, for example. To start, run, and stop these four tremendous motors requires many different regulating units. Many are electronic.

The starting cycle presents the most problems. The drive consists of two 83 000-hp synchronous motors and two 25 000-hp, wound-rotor induction motors for starting and supplemental power. A synchronous and an induction motor are paired. All four are on the same shaft, but with a coupling between the two pairs. All can be started together or each pair independently, in accord with the testing program.

Here are some of the problems requiring the services of regulators, in most cases special ones. During starting the regulators must prevent the speed of the rotating system from deviating from the planned speed-acceleration pattern at any point by more than one percent. The rate of change





An oil-tight pushbutton is made dust tight by soft caps of neoprene that fit over the pushbuttons.

Control for stopping an a-c textile motor with d-c.

in demand during acceleration or deceleration is limited to 30 000 kva per minute. Regulators do this automatically; previous devices gave indication only. In addition to kva control, other regulators limit total current drawn and force the wound-rotor motors to draw equal currents (i.e., share the load) during simultaneous starting. At the time of closing the synchronous motors on the line, regulators determine that the motor voltage matches the line voltage. In normal operation, kilowatt regulators insure that any load beyond the rating of the synchronous motors is picked up by the induction machines.

If the system were allowed to coast to rest, the inertia would keep the shaft turning for nearly an hour. To save time, stopping is done by dynamic braking in about three minutes. After the motors have been unloaded, the dynamic braking field is applied to the wound-rotor motor stators and the secondary current is regulated automatically.

Protection for Wound Rotors

MORE AND MORE whopping big wound-rotor motors are in use, particularly as wind-tunnel drives. If the secondary should become badly unbalanced, as by a fault in the rotor itself, or in the liquid rheostat, or the power cables, an expensive motor failure could ensue. This would seem to call for some fairly simple adaptation of the many differential-protection schemes. But it isn't that easy. The wound-rotor motor has several characteristics that make detection of unbalanced secondary difficult. For example, the rotor currents are at slip frequency, which is a function of motor speed. Rotor unbalanced currents at slip frequency cause a beat frequency to appear in the stator currents. Existing relay schemes will not function properly because of these frequency differences. However, a satisfactory scheme has been worked out employing a bridge-circuit type of rectification and a standard, sensitive d-c relay.

The Not-So-Humble Pushbutton

NOT LONG AGO an *oil-tight pushbutton* was introduced, primarily for machine-tool industries, to keep out oil and coolants. The need was attested by its popularity. It was almost too popular. People used it in places where dust instead of oily vapor is the problem. The oil-tight construction keeps dust out pretty well but not completely. As a result, in some particularly bad locations dust works in, and packs between the button and the shroud.

A simple and novel way has been found around this circumstance. Caps of colored, pliable neoprene are fitted over each button and fastened to the housing at the base of the button by a screw-type metal insert. The flexible neoprene cap does not interfere in the least with pressing the button under it but it does a masterful job of thwarting dust.

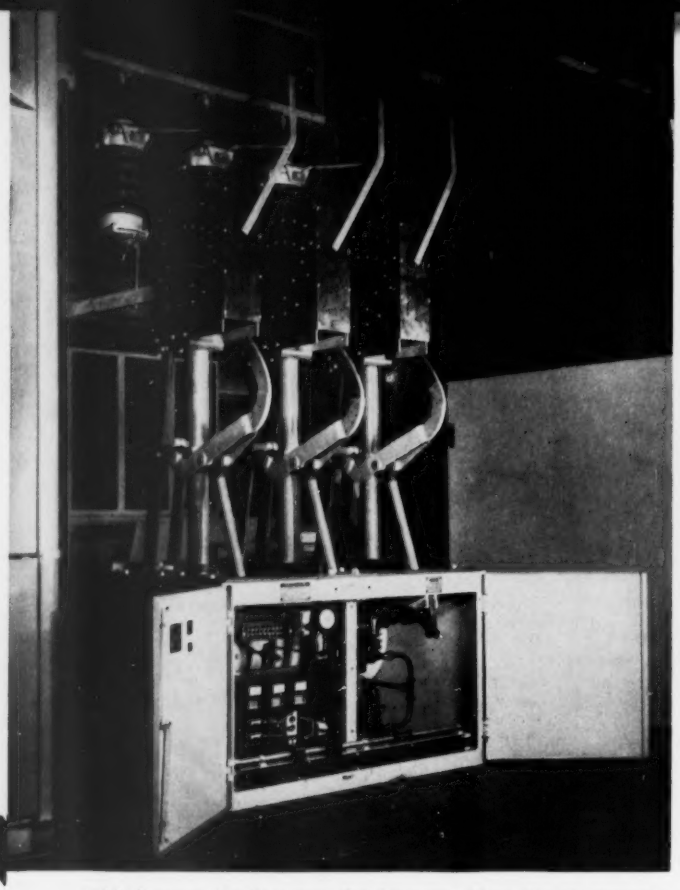
Lever-Operated Button—Human psychology must often accompany technical fact in engineering design. Consider something as simple as a pushbutton. In lumber mills, operators have long been accustomed to steam-driven devices. Push a lever forward to move the what-have-you one way; pull it back to cause the steam engine to reverse it. With steam engines giving way to motors, operators have pushbuttons to contend with. They push a button for one direction; push a second button for the other. Operators aren't so sure they like that; they prefer the old simple back-and-forth lever motion. Also, they shall have it. A simple lever has been developed for attachment to a standard pushbutton by which forward motion depresses one button, backward motion the other. Just like the control for a wheezing old steam engine. And everybody is happy.

Heavy-Duty Button—The industrial pushbutton family is a big one. In case you didn't know, there are many pushbuttons—heavy duty, standard, oil tight, pendant, foot-operated, some with lights, with different colored buttons, and so on. To round out this array, there is a new heavy-duty toggle-type pushbutton of the maintained-contact type.

Furnace Breaker Handles Both Loads and Short Circuits

Probably the roughest service any circuit breaker must face is with electric-arc furnaces. Because of "cave-ins" of the scrap metal during the melt-down portion of the furnace cycle, the breaker must operate frequently. In one typical installation an arc-furnace breaker was called on to interrupt load and overload currents 59 331 times in a 27-month period, or once every 21 minutes. (A power-system breaker is required to operate usually no more than every few months.)

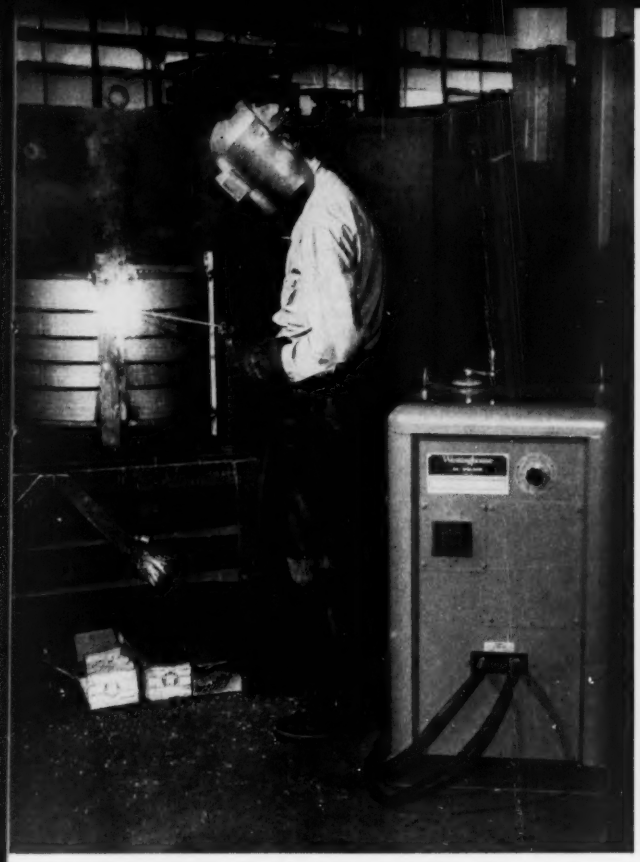
Such frequent load-current interruption would seem to be enough to ask of any circuit breaker. Heretofore, in arc-furnace installations a separate breaker has been used for interruption of short-circuit currents. Now the furnace breaker does both jobs—frequent operation on loads and overloads and infrequent operation on heavy short circuits. It is a compressed-air breaker, with arc chutes redesigned to give it ability to interrupt 500 000 kva on 34.5-kv lines. Tests on this circuit breaker in the high-power laboratory show it capable of handling the frequent routine load openings and also several primary-fault operations yearly without high maintenance.



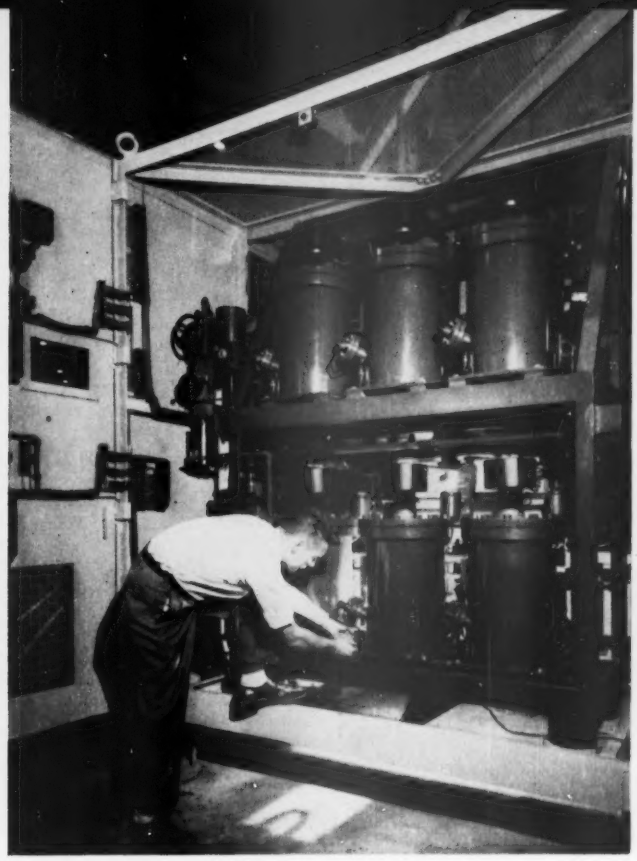
This furnace breaker can also interrupt short-circuit currents.

Heating...

This is a pit-type furnace useful for general heat-treating purposes where top loading is desirable.



A rectifier welder is much lighter because of aluminum windings.



A 1000-kw, 250-volt, metal-enclosed ignitron-rectifier unit.

Welding... Rectification

Pit-Type Retort Furnace

IN MANY FACTORY situations it is easier to lift pieces or a batch of pieces in and out of a heat-treating furnace than to push them through horizontally. For these a new pit-type retort furnace is the thing. This furnace is basically a cylinder about six feet across and ten feet high. Generally the lower two thirds is set below the floor level, making it convenient for the operator to observe and control loading and unloading. Parts to be heated are lowered into a central chamber; between this chamber and the outer wall are heaters—either gas or electric. A fan in the bottom of the plug-type lid maintains temperature uniform throughout the charge during the heating cycle. Any standard atmosphere can be used. Operation is completely automatic. Gas heaters are fired by spark plugs. The furnace has a capacity of about 800 pounds per hour net. The furnace is used for cycle annealing, gas carburizing, hardening, and dry cyaniding.

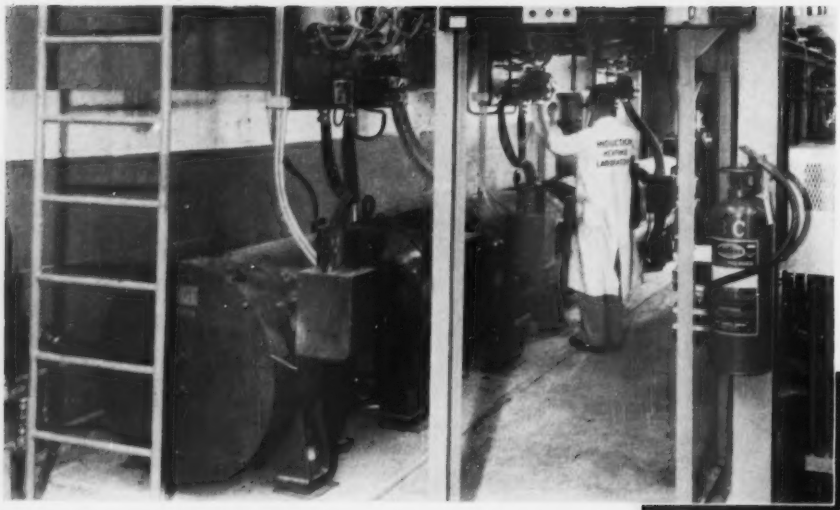
General-Purpose Heat-Treating Furnaces

RADIANT-HEATING furnaces are generally custom-built for specific applications. An important new furnace, however, is for the run-of-mine jobs that industry has in great variety. It is a horizontal, single-end, batch-type furnace with built-in quench and can be either gas or electric fired. The furnace is arranged to be used with any of the standard atmospheres. Only one operator is required because the only manual operations are loading and unloading. Furnace temperatures up to 1850 degrees F are possible. The hourly output is from 200 to 400 pounds net. The furnace can be used for bright hardening, carbonitriding, carburizing, Martempering, normalizing, nitriding, or stress relieving.

Aluminum Reduces Rectifier Welder Weight

THE RECTIFIER-TYPE d-c welder first appeared on a commercial scale in 1949. Now it has been significantly improved. Mostly this comes about by the development of a combination three-phase transformer and movable-core reactor, called a Transactor unit, wound with aluminum coils. Use of aluminum windings is in large measure responsible for an important reduction in weight; the 300-ampere unit has decreased in weight from 510 to 400 pounds. Some reduction in overall dimensions also results.

Axial-flow ventilation, with the fan located in the top of the unit and the air intake located at the bottom, permits incoming air to flow vertically through the welder, following natural convection. This natural flow results in maximum cooling with minimum-size cooling fan and motor. The coils of the Transactor unit, located directly above the bottom-mounted rectifier, are wound with large ventilating ducts to insure maximum cooling. Overload protection is provided to prevent damage to the welder should an excessive temperature result either from overload or from failure of the fan to operate.



Because of a new type heat exchanger, high-frequency induction heating generators are both lighter and smaller, and use only about half as much water. No water gasket seals are required. A switch from water to air cooling or vice versa can be made quickly without change in rating. The heat exchanger is removable.

More Powerful Sealed Ignitrons

A NEW, SEALED, ignitron mercury-arc rectifier is capable of rectifying 750 kw at 250 volts direct current with only six tubes, each of which is only 12 inches in diameter.

Sealed tubes of less than eight inches are usually expendable; when one fails no attempt is made to repair it. However, the new larger tubes are constructed so that the welds can be cut, the tube repaired, and then rewelded—a factory operation that makes the tube as good as new.

Many installations of sealed tubes eight inches in diameter (WL 688) have been in operation for five years, carrying 500 kw at 250 volts direct current on six tubes continuously with the original tubes still in service. The new 12-inch sealed tube, designed along the same line, pushes the load ceiling up by 50 percent.

They are light enough to be handled by two men and are mounted in cubicles. The tubes simplify rectifier installation in industrial plants, mines, railways, and locomotives where sealed tubes are applicable.

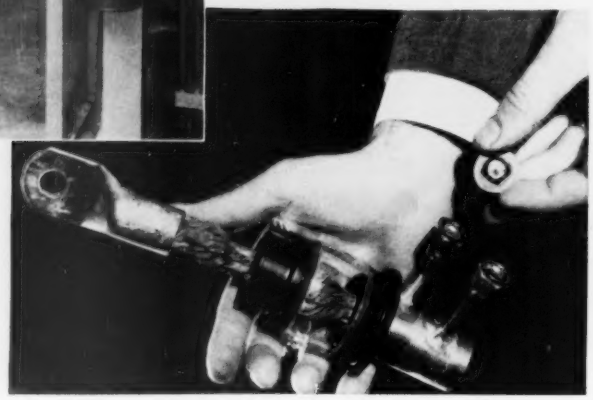
A Modernized 25-Kw Induction-Heating Generator

A NEW 25-kw, 450-kc, r-f generator has been developed that supersedes the 20-kw equipments formerly produced. By utilizing recent developments in saturable-reactor application, by exploiting the experience of a decade in industrial-tube oscillator design, and by simplifying circuitry as well as control, an r-f power source becomes one fourth larger than its predecessor—but costs less and offers greater dependability without close attention.

Vernier control of output power in the new equipment is accomplished by saturable reactors in the plate circuit; these static devices replace thyratron tubes that had limited life and complicated the power-output control circuit. Saturable reactors also offer possibilities for automatic control of output power that were heretofore unattainable.

In this experimental water-cooled rectifier, a wafer of germanium only ⅞ inch in diameter and 0.015-inch thick delivers 200 amperes (average) direct current at 100 volts. The rectifier is still in the developmental stage. While ratings are not yet exactly known, the peak back voltage is expected to be about 110 volts and the forward voltage drop at 200 amperes average (600 amperes peak) will be slightly less than one volt.

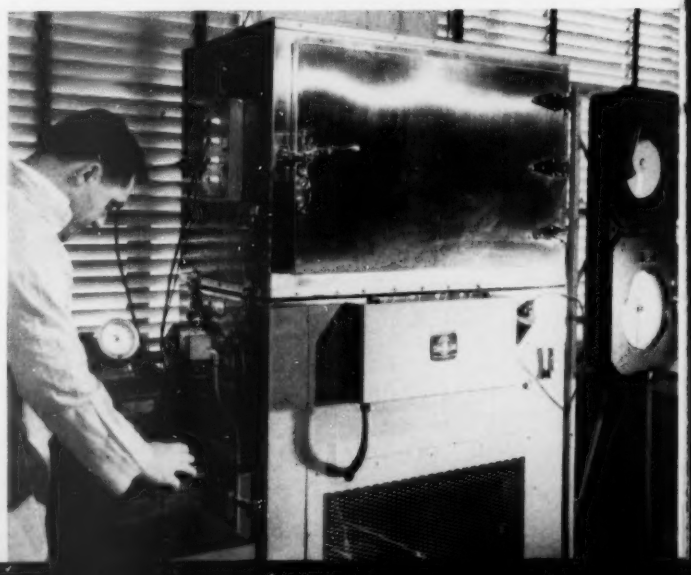
Water-Cooled Germanium Rectifier



The new equipment includes a built-in water-cooling system that eliminates condensation on components, assures longer tube life, provides cooling-water economy, and contributes to overall trouble-free performance. Distilled water is circulated in the generator components and heat removed through a heat exchanger to the raw city water.

Other features of the new 25-kw generator are: regulated filament voltages, electronic keying of output power, and a complete complement of protective devices. Provided also is an improved, more flexible worktable. It is the latest design in a family of generators that has rapidly expanded to meet the demands of industry.

Measurement

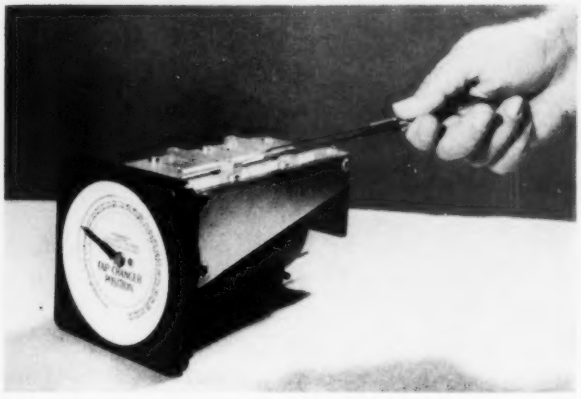


The heart of a portable recorder, such as is used by power companies for voltage and current surveys, is the clock mechanism. Previously mechanisms as used in good alarm clocks have been employed. A new one, specifically designed for recorder service, is smaller and is dust tight. The escapement, which is the part most likely to wear, is made in a cartridge easily removed for a new one. By changing a gear the chart rotates in one day or seven.

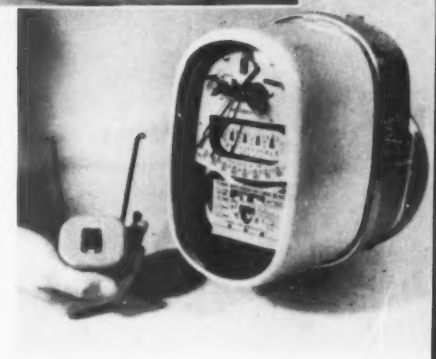
Type A Recorder ▶

The pointer on this 250-degree position indicator is driven by a Synchrotie motor. The motor has much more torque than the old synchroscope drive. Response is quicker. The indicator is accurate to one percent angular position of the pointer.

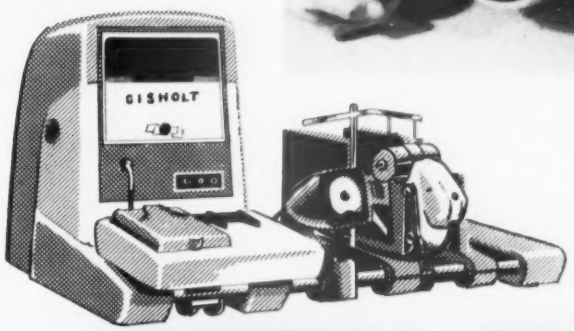
▼ KS-24 Synchrotie Position Indicator



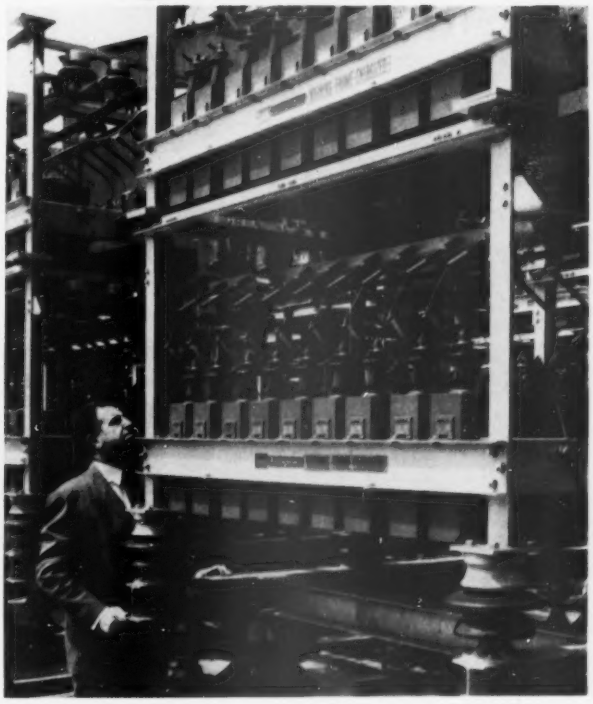
A new combination high-capacity demand and watt-hour meter is operable on currents up to 200 amperes without external current transformers. The split-core transformer is compensated for loss by an extra winding.



The new Dynetric balancer has been made more sensitive, much smaller, and much easier to use and can be used at higher speeds. ▶



This 21 600-kva, 60-cycle bank of capacitors at the high-power laboratory at East Pittsburgh can be operated at 1.7 times normal voltage to give it 65 000 kvar, the largest amount of reactive kva for test purposes at any industrial laboratory. It can be used to simulate the capacitance of long transmission lines or cables for circuit-breaker evaluation or for tests on switching of shunt- or series-capacitor banks. The bank is insulated for operation at voltages as high as 198 kv, line-to-ground (345 kv, line-to-line). ▶



and Test

High-Power Laboratory Humidity Chamber

With growing demands, particularly by government agencies, for environmental testing, this humidity chamber has been added to the East Pittsburgh laboratory facilities. Ranges in temperature from 32 degrees F to 160 and in humidity from dry air to saturation are possible. A program controller provides any desired environment cycle.

Hi-lites in Pictures

(*A*) This is one of
and can deliver 15
and *C*) Here is a 1
Until the availabil
and larger railroa
E) This rewinder
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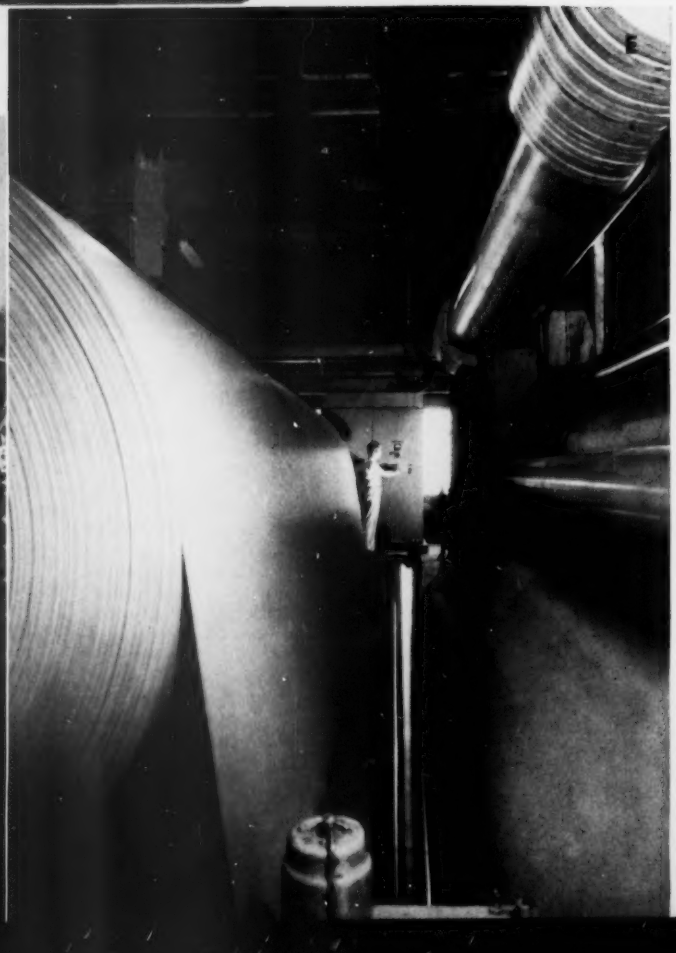
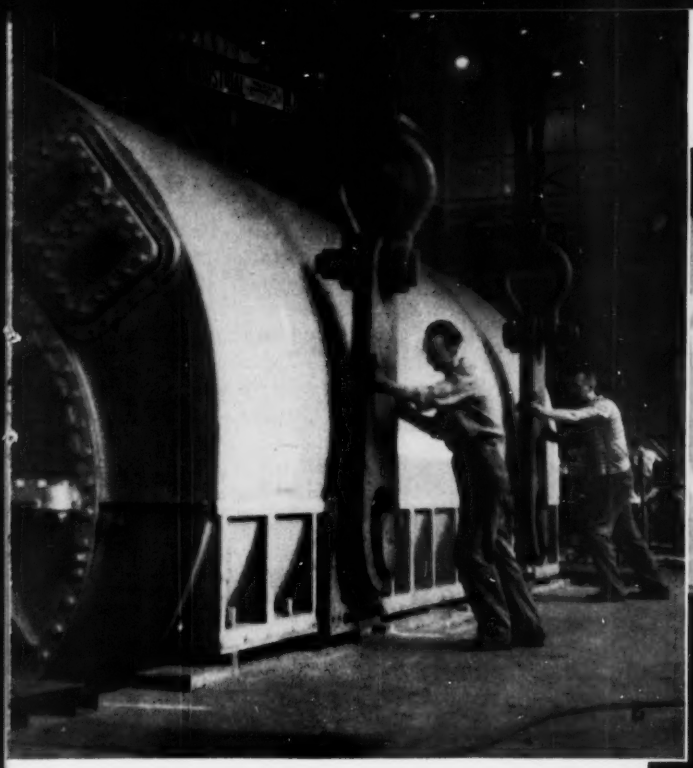
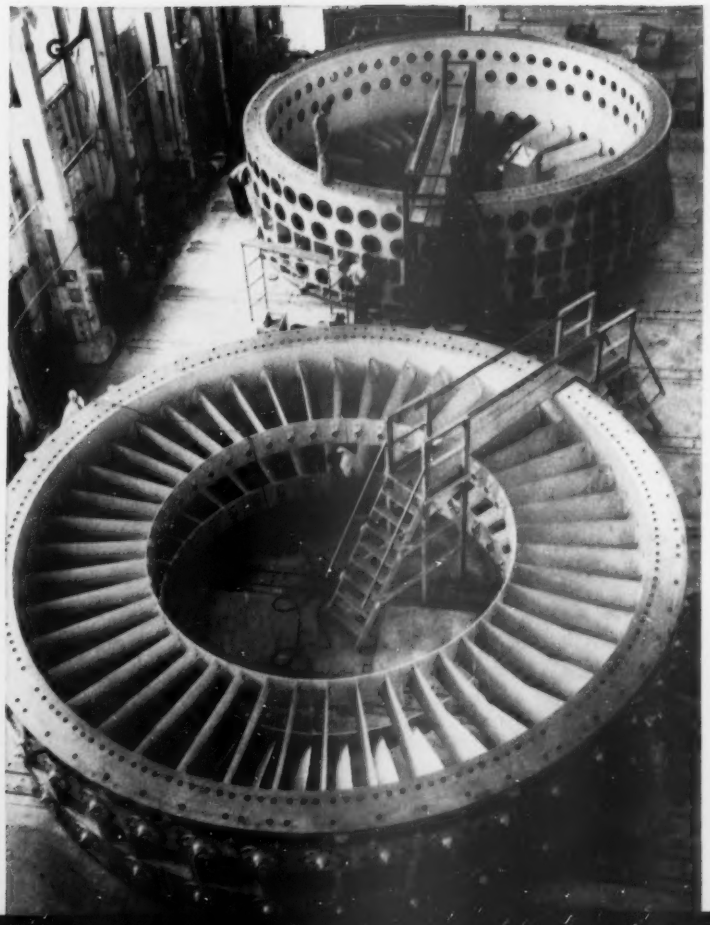




the new 43-inch diameter rotors. It is 25½ feet between bearings
6 250 kw at 30 pounds gas pressure and conventional cooling. (*B*
10 000-kw generator with rotor being shipped, completely sealed.
ity of the enlarged testing and loading facilities at East Pittsburgh
cars, the largest machine shipped intact was 60 000 kw. (*D* and
of the West Virginia Pulp and Paper Co., rewinds 20-foot wide
at the unusually high speed of 5300 fpm, and this may be further
trols for main and back-stand motors use magnetic amplifiers. (*F*
stator sections for the Tullahoma wind tunnel being bladed.

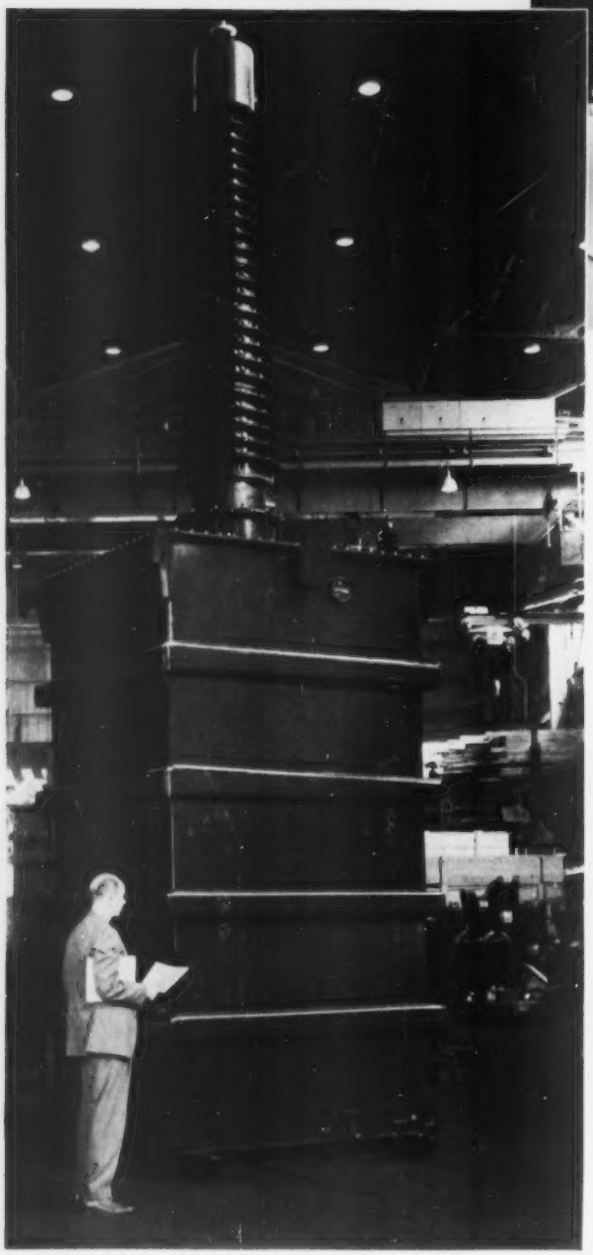


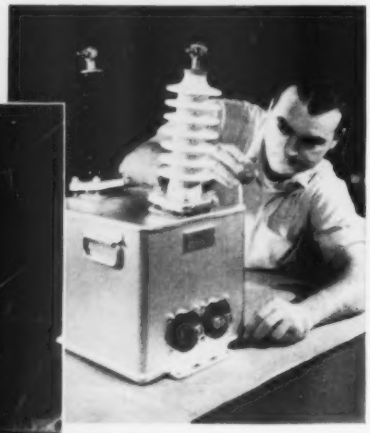
The Electronic Balancer Improved

EVEN THE near perfect can be improved. The Dynetric balancer, introduced in 1937 by Westinghouse and the Gisholt Machine Company, as a means of electronically detecting amount and location of machine unbalance, was one of those rare devices that achieved a high degree of perfection at the outset. Few changes have been required since.

However, a little more than three years ago designers began an overhaul in the light of new knowledge and new materials. The result is an improved balancer (type S), better in many ways. The vibration-sensing pickups are physically much smaller. An unbalance that causes 25-microinch movements of the pickup gives a displacement of the unbalance meter needle of three fourths inch—eight times as much as in the original machine. Magnitude and location of unbalance are shown simultaneously instead of in sequence as before. The maximum speed at which objects are run during the balancing operation has been stepped up from 2000 to 3000 rpm. The physical arrangement of components has been simplified by separating the meter from the amplifier so each is located to its best advantage and operator convenience.

An oil-immersed, single-phase, potential transformer, with graded insulation, for use on a 330-kv system.





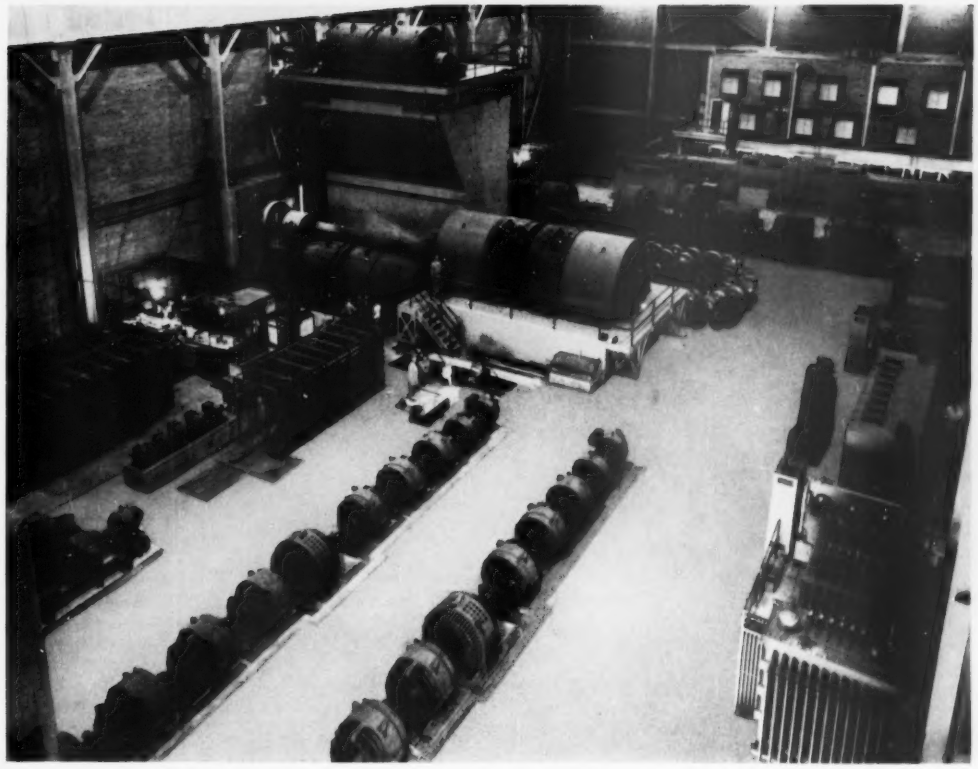
Generating voltages—long stationary at 11 and 13.8 kv, are beginning to rise. Voltages of 15, 18, 21, and even 23 kv are not uncommon. Air-insulated instrument transformers for these voltages have not existed—and power companies don't like oil-containing apparatus inside powerhouses. A new potential transformer has been developed suitable for operating voltages up to 25 kv and impulse levels of 150 kv. Following successful experience with units for lower voltages, these transformers are compound filled. Air is withdrawn from the unit under heat and vacuum before it is filled.

Outdoor Low-Voltage Current Transformer

ONE MIGHT suppose the best way to make a weatherproof current transformer would be to seal the core and coils in a metal case so tight that water can't get in. Instead, in the new outdoor, through-type current transformer (FWO) no serious attempt is made to keep water out. Holes are purposely left in the bottom for free water to drain through. To make an absolutely watertight case that stays that way is more difficult than to keep moisture out of the core and coils by using the new water-repellent synthetics, particularly of the silicone type. The core and coils are assembled on a tube of silicone-glass laminate. Coils are treated with silicone, which maintains high dielectric strength when wet. The metal case is given the Coastal finish developed originally for tanks of distribution transformers used in salt-air regions. After core and coils have been assembled in the painted case the whole unit is given a silicone-varnish dip. This construction has been proved by test to be excellent for outdoor service at voltages up to 600. Other features of the unit include an oval-shaped tube instead of a circular one for the core. A biased core gives higher accuracy for a given size.

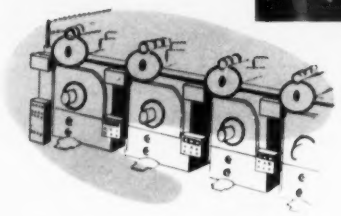
A Demand Meter That Both Records and Warns

INDUSTRIAL-PLANT operators need a warning when the plant load is climbing to a new demand rate-change point. The kva-demand recording instrument employs a ball to summarize vectorially the disc speeds of the two meter elements. An addition of a mechanical device would introduce friction that might make the ball slip. A frictionless light beam is used with an electronic amplifier to enable it to give the desired warning without interfering with its measuring and recording function.



A slabbing mill of the Great Lakes Steel Corporation is driven by a pair of 12 000-hp twin motors and a 4000-hp edger motor (visible on its private "balcony" above the main roll twin motors).

Steel



Aluminum Magnesium

Many Outstanding Steel-Mill Installations

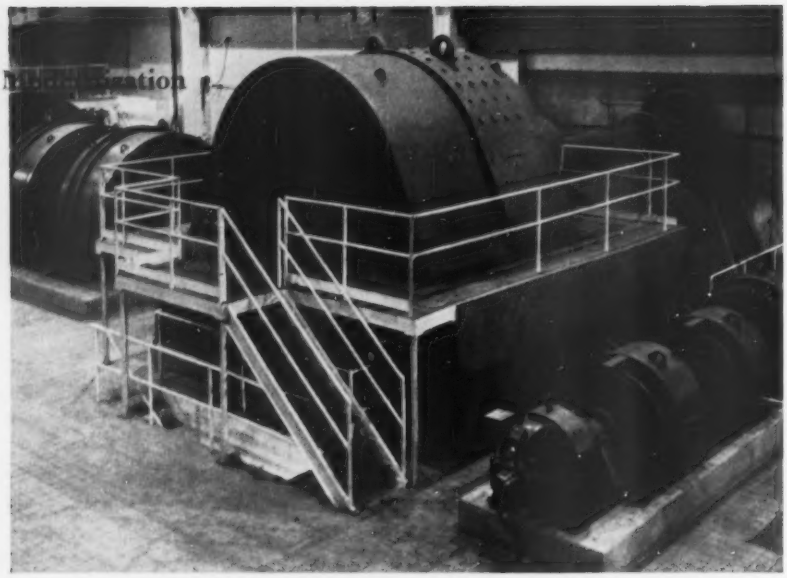
AMONG THE technically more interesting recent steel-mill installations is one now operating in Texas. While Texas is well known for things of exceptional size, it is purely coincidental that the *72-inch reversing hot-strip mill* built by the Lone Star Steel Corporation is a particularly big one. It was built in part to help meet the demand in the Southwest for large pipe. It can produce strip (skelp for pipe) up to 66 inches wide and as much as 9/16 inch thick. To drive the mill requires a 7000-hp, double-armature motor supplied from a 6000-kw, synchronous-driven, motor-generator set. The number of adjustable-voltage auxiliaries also is uncommonly large as are the power requirements. For the slab shear, slab reheat furnace, furnace coiler, mill pinch roll, remote table, flying shear, and finished strip up-coiler there are two motor-generator sets with a total of twelve generators, which have a combined capacity of 3430 kw.

An outstanding *80-inch continuous hot-strip mill* was placed in operation in eastern Kentucky last year. The six finishing stand motors, totaling 25 500 hp are connected to a common bus and supplied from three 6000-kw m-g sets. Each m-g set consists of two 3000-kw, 700-volt, d-c generators and an 8400-hp, 90 percent power factor, 6900-volt, 3-phase, 60-cycle, 360-rpm, synchronous motor. The supply generators have differential series-field windings to give an inherent slightly drooping voltage regulation characteristic sufficient to assure stable parallel operation and good load division. The six generators are excited from a 105-kw variable-voltage exciter under control of a Rototrol voltage regulator. A special feature of the control is the provision to reduce the voltage to an adjustable preselected value so that each strip can be started into the finishing mill at a reduced speed. Then the voltage and speed are returned to normal at an adjustable preselected rate during the rolling. This mill is intended to produce long strips, and the ability to adjust the mill speed during the rolling of each strip improves the gauge accuracy from end to end.

A large part of *France's huge new integrated steel mill*—Sollac—is now running and the remainder will be in a few months. This installation includes a 45-inch reversing blooming mill, an 80-inch hot-strip mill supplied by ignitron rectifiers, a five-stand and a three-stand cold-strip mill, four skin-pass mills, and cleaning and pickling lines.

Two *universal slabbing mills*, the most heavily powered in the world, went into service last year at the Fairless Works of U.S. Steel and at the Great Lakes Steel corporations. These mills require heavy power to break down ingots weighing up to 46 000 pounds. The main rolls are driven by double-armature twin motors, with an output of 12 000 hp.

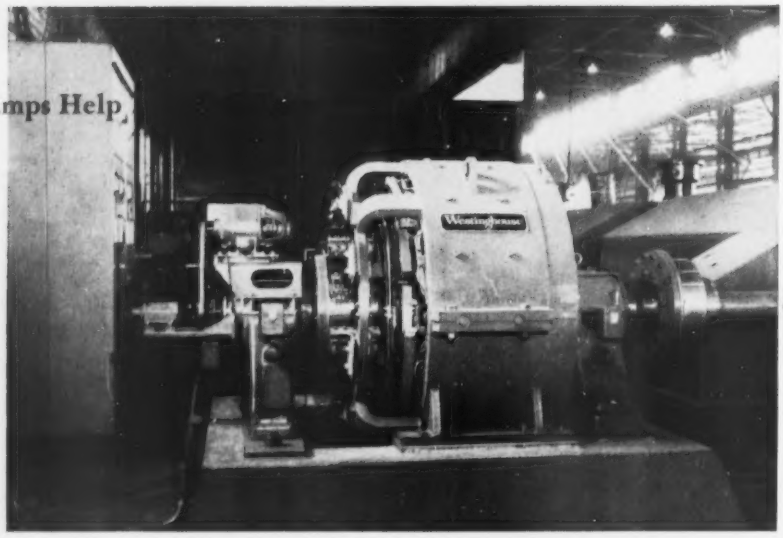
Mill Modernization



Sometimes the major portion of an engineering accomplishment lies not in the novel features of the apparatus itself but in installing it. Particularly is this true when new equipment is placed in an old plant without disturbing production. For example, an eastern steel mill recently completed the erection of a 46-inch modern blooming mill in the middle of an old steam-driven plant with no loss of tonnage. As to electrical equipment, this involved erection of an 8000-hp twin-motor drive (*left*); for a short while, an old steam-driven mill was running in the motor room. At the same time and in the same crowded area a four-stand, 30-inch bar mill was erected using individual 750-hp, high-slip motors.

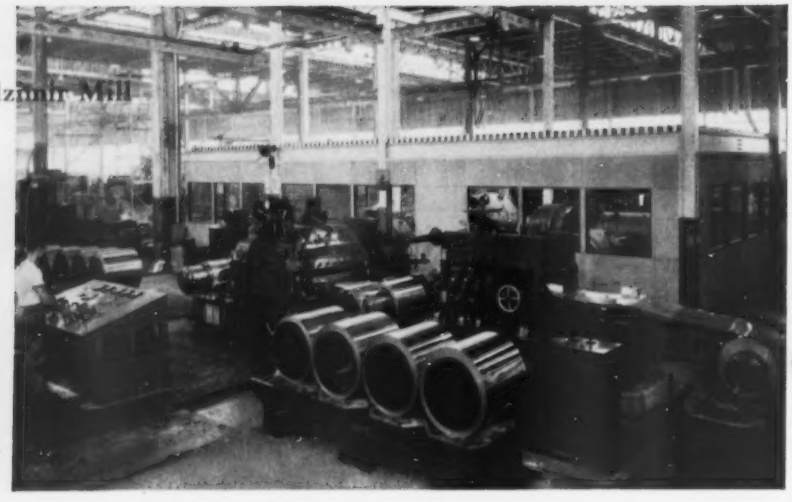
The Colorado Fuel and Iron Corporation had a somewhat similar chore. However, a 25-inch structural mill was changed over from a-c motor drive to a 4000-hp, d-c drive and other major changes made in the speedy time of 21 days. This is part of a modernization program in which an old structural mill used principally to roll structural shapes and track fastenings can now be used equally well to roll rounds for seamless pipe. The mill can operate either as a two-high reversing mill for rounds or as a three-high continuous mill for structural shapes. An unusual method was adopted to cool the motor room. The air is humidified, significantly lowering its temperature and thus aiding the cooling and benefiting the motor brushes. This is possible only because of the low humidity prevailing at Pueblo, Colorado.

Magamps Help



Magnetic amplifiers helped with a difficult rolling-mill problem for the Algoma Steel Corporation in Canada. A military application required billets rolled to a rather unusual precision. Finished billets were to be three inches on a side with the diagonal held to $^{1}/_{64}$-inch tolerance. This was to be done in a six-stand mill in which the first five stands are gear driven by a 4000-hp, low-slip induction motor and the sixth by a 1000-hp d-c motor supplied through an ignitron rectifier. The difficulty is to get these two motors to team together under all conditions of load and supply voltage. The a-c machine is much less sensitive to variations in a-c line voltage than the rectifier-supplied d-c machine. To provide good speed harmony between the two motors a pilot generator is placed on the shaft of each motor. The outputs of these two pilots are compared and the result fed to a two-stage magnetic amplifier, which also takes a-c line voltage into account. The output of this regulating system operates on the phase-shifting circuit of the rectifier. This alters the voltage on the d-c motor to make its speed match that of its a-c running mate.

Sendzimir Mill



This high-speed Sendzimir mill is operated by Chase Brass & Copper Co., Inc., subsidiary of Kennecott Copper Corp., to roll brass to thin strip. It is driven at speeds up to 1000 feet per minute by a 500-hp mill motor, with a 150-hp motor on each reel. The roll is 25 inches wide. On the average, brass is rolled from 0.050 inch down to 0.004 inch, although strip as thin as 0.0025 has been produced on this precision mill.

New Control of Tension in Steel Strip

TENSION in steel strip moving two thirds of a mile per minute is controlled over a range of 20 to 1 by a new type of tensiometer regulator that has a total movement of only 100 mils—less than one eighth inch. Its predecessor had a travel of two to three inches. The shorter travel makes for faster response. Chart records show that the operator of a temper-pass mill can effect a change in strip tension from 8000 pounds down to 6000 pounds in one half second. If the operator sees a bad edge or other defect in the strip, he has a better chance of reducing the tension before a tear occurs.

The tensiometer gets its signal from a reluctance-type pickup, similar in principle to that used in phonograph-record players. The signal is amplified by magnetic amplifiers that replace rotating devices formerly used. A special circuit takes the tensiometer out of operation when tension falls to less than 800 pounds. This prevents the tensiometer from trying vainly to maintain tension during start up, shut down, or when the strip breaks.

The tensiometer is all electric. In contrast to systems that are part mechanical this requires no dampening, which might have to be readjusted when operating tension is changed over a wide range. The previous type of tensiometer is widely used and will continue to be preferred for some tension-regulation applications. The small-travel tensiometer is better suited where the range in tension is wide and also where rapid adjustment of tension is required. In addition to controlling tension it gives a continuous indication to the operator. Ability to control tension closely during speed change reduces the amount of off-temper material produced.

The first use of the new tensiometer was to control the tension between stands of a two-stand skin-pass mill at the Kaiser Steel Corporation, Fontana, California.

Big Regulators—for Aluminum Lines

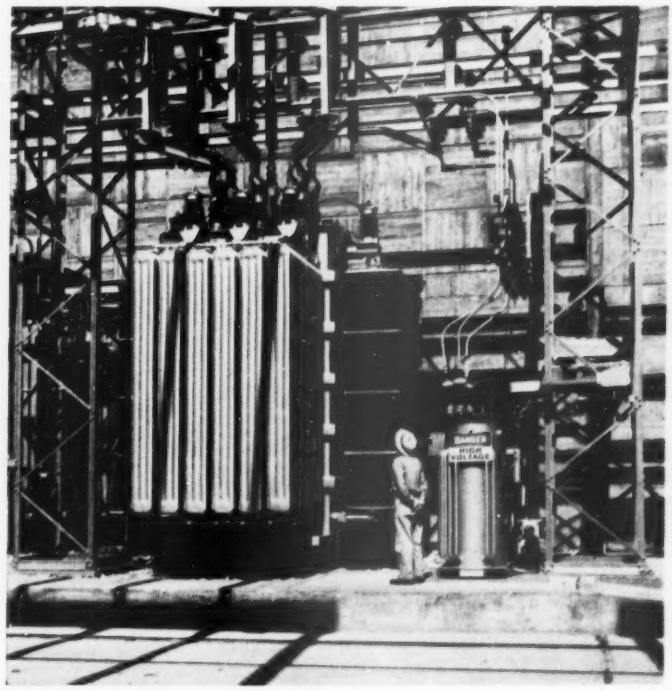
WHEN ONE hears of power regulators of sizes from 40 000 to 80 000 kva, one thinks of power companies. However, most of the largest voltage regulators are for the new and large electrolytic aluminum plants. The purpose of all of them is to control voltage to the "pot" lines, but the sizes and regulating ranges differ considerably.

One plant is using four single-rating, 60 000-kva units. These regulate voltage ± 7½ percent around a 13 200-volt base using tap-changing underload equipment. They supply four pot lines. These regulators are among the first to use an air-insulated transfer switch. This is a heavy-duty transfer switch suitable for frequent operation. Because it is air insulated it can be quickly opened and is immediately available for inspection and servicing. An oil-insulated transfer switch, while physically smaller, involves oil filtering and handling, and makes inspection and maintenance more complicated and difficult. The new transfer switch, in its fundamentals, was developed as a heavy-duty contactor for submarines.

For another aluminum-reduction plant, three units, each with a triple rating of 40 400/53 900/67 300 kva, are used to feed a single pot line. These control voltage from a 13 800-volt base between 15 180 down to 1620. This is done by seven no-load tap-change positions and one ± 1380-volt underload tap-changer mechanism. The no-load tap changer has a continuous current rating of 3000 amperes.

A third plant gets the largest units of all. These have one rating of 80 000 kva each with no-load and underload tap changers that provide pot-line voltages of 15 180 to 2120 from a 13 800-volt base.

60 000-Kva regulator at a Washington plant of Aluminum Co. of America.



Stirring without a Rod

THE MELT in an electric-arc furnace, like soup, should be stirred. Stirring speeds up the "cooking" and provides more uniformity of the bath. But just how does one stir a "soup" of tons of liquid steel? Men have done it by hand (rabbling)—which has drawbacks. Cranes sometimes tow a steel ingot around in the molten metal. But that's not too good either.

A new way is to do it magnetically. A d-c excited electromagnet (i.e., one north and one south pole) is slowly rotated below the arc furnace. The strong flux field enters the furnace, passes through the melt, and out to the other pole of the magnet. In so doing it creates currents in the steel that establish a circular flow within it. The system requires about 165 kw to power the rotating electromagnet, which is driven by a 50-hp motor.

Rolling Aluminum Sheet with a Taper

THE WING section for an airplane is a cantilever member. For maximum strength with minimum weight the wing-skin plates should be tapered. They should be thicker at the fuselage than at the tip. The new trick is to roll it that way. The Reynolds Metals Company is building a mill for service

this year that will roll a 40-foot aluminum sheet 11 feet wide, which is thicker at one end than at the other by as much as one half inch. This is accomplished by a rather involved control that runs the screws on the rolls up or down as the sheet passes through. That in itself would not be difficult, but the control must also take into account the stretch in the housings and distortion of the screws. Although each of the four mill posts has a sectional area of 8.3 square feet, the stretch is a few thousandths of an inch—because the pressure on each post during rolling is 2½ million pounds.

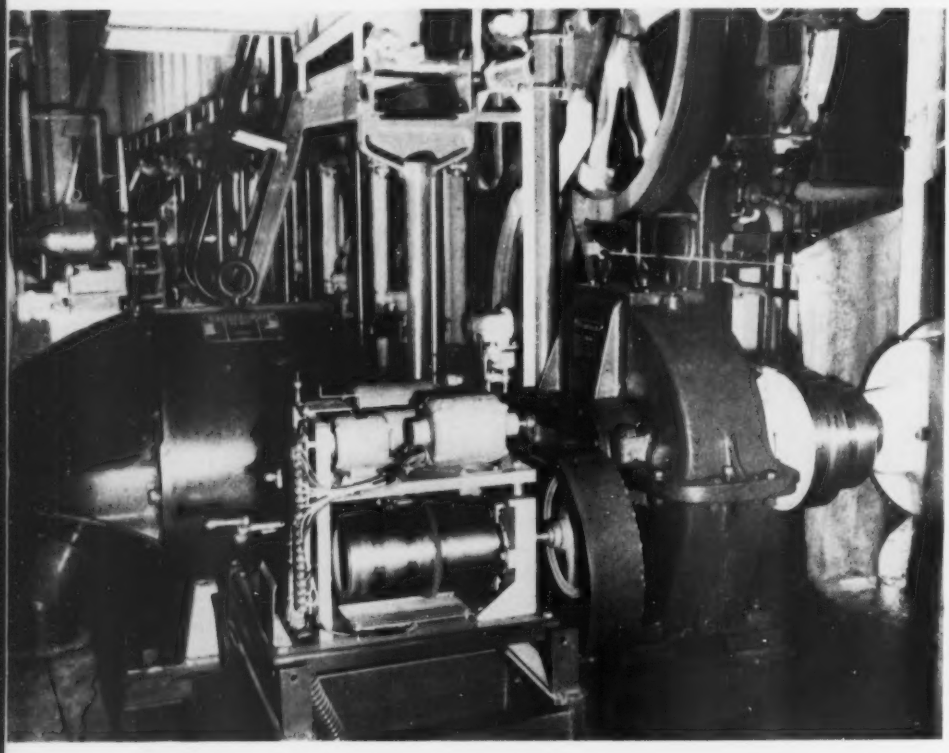
To relieve this situation a water-cooled rectifier transformer is being used. The floor area covered is less than half, the weight is 35 percent less, and the cost is lower. Where water is scarce or warm, a water-to-air heat exchanger can be used. Further economies can also be realized by omitting all no-load taps on the rectifier transformer and allowing the main regulating power transformer to provide the necessary voltage changes. This system is especially attractive if more than four rectifier transformers are supplied from a single voltage-regulating transformer.

Smaller Transformers for Aluminum Lines

THE TRANSFORMERS supplying power to ignitron rectifiers in an aluminum-reduction plant might appear to be an essential but minor accessory. However, rectifier transformers are of major importance and in some cases they determine the plant layout. Cooling a rectifier transformer is the problem. And a 75 000-kw plant has eight or ten of them. Self-cooled transformers—the type always used—have a large number of radiators to be maintained. Not only is the floor space they themselves occupy considerable but also, because of the close coupling between rectifier and transformer, they sometimes require that the rectifiers be spaced wider apart than their own needs demand. Thus, because of transformer size, the rectifier room is larger than it would otherwise need to be.

A Rolling Mill for Magnesium

AMONG THE more interesting new metal-rolling mills is one to roll, not steel, but magnesium. This is being erected by Dow Chemical Company at Madison, Ill., and is expected to be turning out a wide variety of magnesium coiled-sheet products from structural shapes to thin strips early this year. The plant will include a reversing mill to reduce one-ton magnesium ingots to strip and three mills for producing various coiled magnesium products. The fact that magnesium is the lightest of structural metals does not mean that the power required for rolling it is small. The four mills require a total of 14 000 hp in main drives. The reversing hot mill alone has a 6000-hp main-drive motor and one of 1500 hp for driving a pair of vertical edging rolls.



Paper
Textile
Glass
Mining
Petroleum

▲

The Mechanical-Differential Paper-Machine Regulator Proves Itself

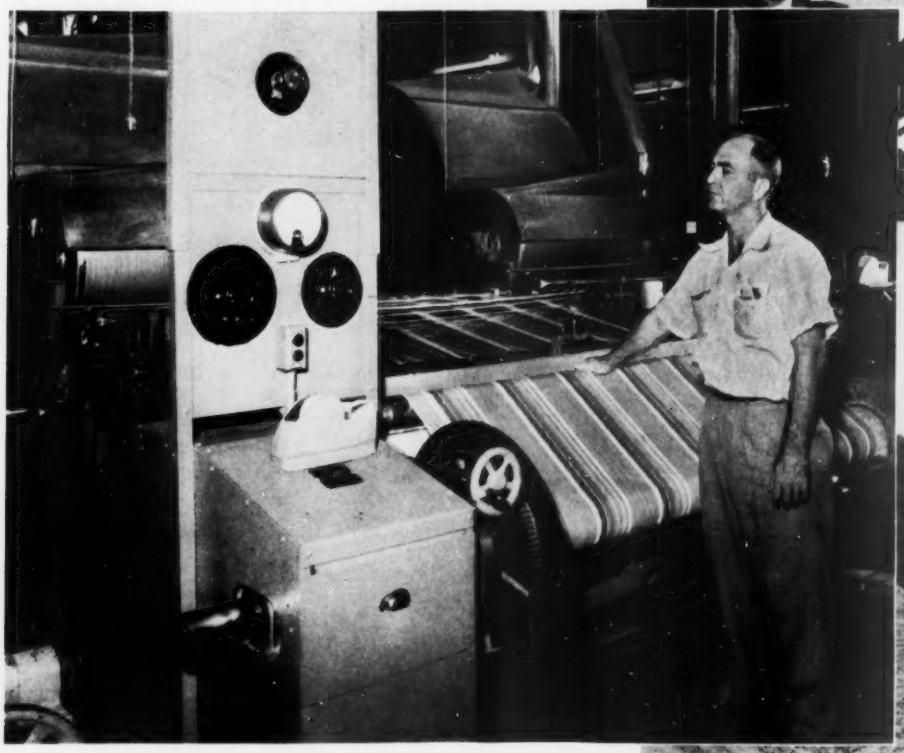
THE MECHANICAL-DIFFERENTIAL Magamp type of paper-machine speed regulator announced last year received its first trials several months ago, and has already established an extraordinary reputation for performance in the paper industry. In the plant of the West Tacoma Newsprint Company in Washington, where the first commercial installation was made, saleable paper was produced with the initial startup.

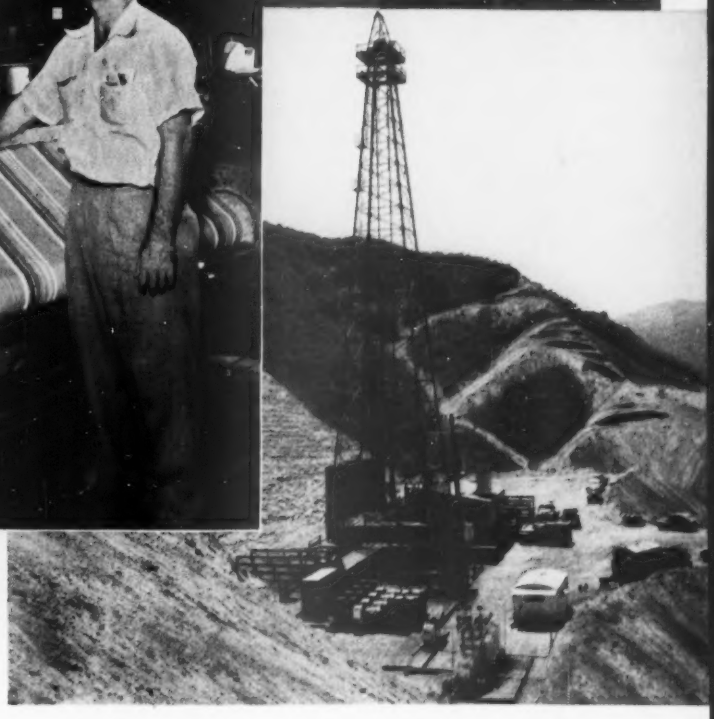
By October 1, 1953 some 50 of these regulators were under construction for 12 different plants. Many are for old mills and are to replace obsolete carbon-pile regulators.

The differential unit consists of a pair of cone pulleys, driven from the section of the machine whose speed is being regulated, a synchronous motor driven at a speed proportional to the master-reference speed, and a differential-gear system for detecting the speed difference between the section and the master synchronous motor. This difference is converted to electrical signals, rectified, amplified by magnetic amplifiers, and applied as a correction to the driving motors. Under steady-state conditions the only moving components are the pulleys, gearing, and synchronous motor. The differential regulator, acting with the magnetic amplifier, does a precision job of speed regulation to hold the various paper-mill sections in step.

Textile Slasher Drive without Tubes or Rotating Exciter

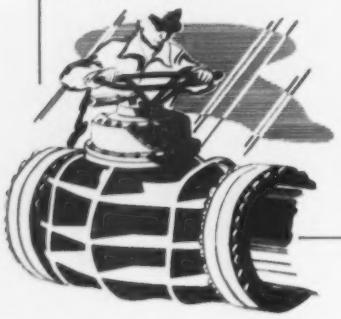
APPARATUS DESIGNERS must take into account not only the desired performance but also problems involved in servicing it. Maintenance men in the average textile mill are not familiar with electronic circuits. Yet textile mills, like most industries, are calling for higher and higher grade performance for most of their basic operations. This is true in the case of



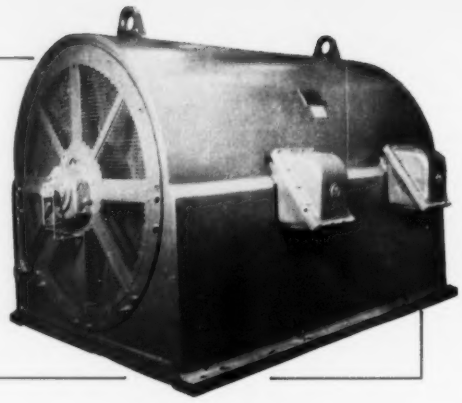


(*Upper right*) A fusible motor starter has been produced for outdoor service that is required by widely scattered motors driving pumps in old oil fields. (*Above*) A packaged drive for textile slasher at Avondale Mills uses a selenium-rectifier exciter. (*Right*) The Tide Water Associated Oil Co. is using an all-electric, 1500-hp drill rig to look for oil at Ventura, Calif. Power is supplied by 16.5-kv lines.

King-Size Explosionproof Motor



The petroleum industry has been requiring larger and larger explosionproof, high-speed motors. Until recently the largest available explosionproof, two-pole motor was 1250 hp. This new one is 2½ times that big; it develops 3000 hp. It has a tube-type, air-to-air heat exchanger. While incorporating no new principles, it is a problem to make so large a housing explosionproof. Each end of the motor is designed to resist an internal explosion force of two million pounds. As this is written the motor is being readied for Underwriters' Laboratories tests.



the slasher, which is a machine that dips several hundred strands of yarn (you and I would call it thread) in a sizing material, dries, and winds them on a "beam" or spool. The magnetic amplifier has made it possible to provide proper winding speed and tension and proper coordination with the various sections of the slasher without introducing electronic tubes into the textile mill.

Last year a multimotor slasher drive with magnetic-amplifier control was introduced. It is a packaged drive. The motor-generator set, booster, and control are contained within a single metal cabinet. Simplification has been further achieved by eliminating the rotating exciter; direct current for the field of the d-c generator comes from a selenium rectifier. This reduces the number of brushes, commutators, and bearings to be serviced. The fact that the whole unit is a single package reduces the space occupied on the mill floor, eliminates much of the initial wiring and installation cost.

A New Motor Panel for Old Oil Wells

A FAMILIAR SIGHT in western Pennsylvania and other old oil regions is the derrick, with the long walking beam, slowly teetering back and forth to suck up the few remaining barrels of oil still accumulating in the almost spent well. Originally these were driven in gangs by long rope or cable from a centrally located engine. Now they are individually motor driven. And motors must have starters. These must be simple, foolproof, and weatherproof—for they are generally fastened to a pole adjacent to the motor.

An improved starter has been developed for this service. In one weather-tight metal housing is a combination starter, contactor, overload relay, disconnecting switch, time switch, and lightning arrester to provide adequate protection for both motor and circuit.

Coal-Mining Machines Go A-C

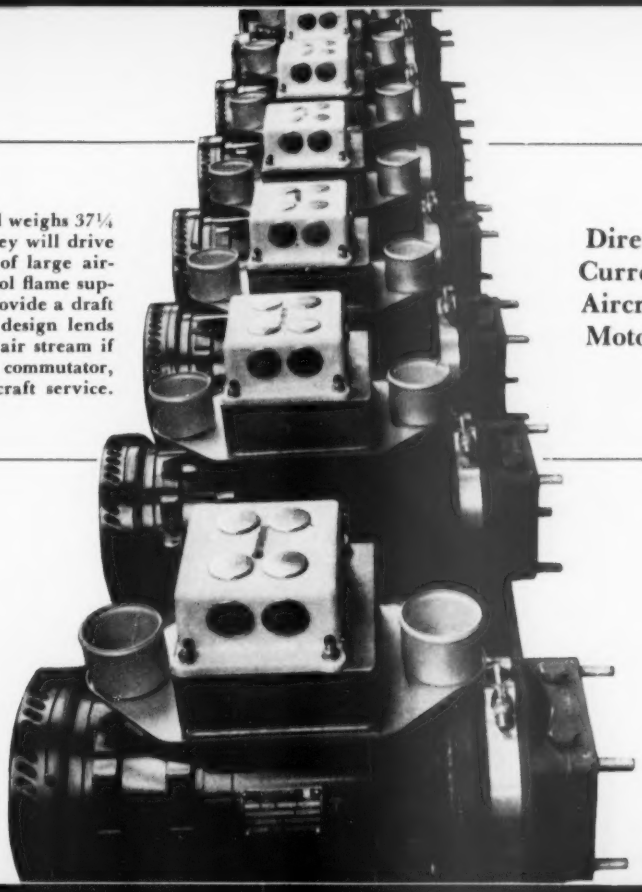
MACHINES for continuous mining of coal are being steadily developed and improved. One of the recent trends has been to adapt them to a-c power supply in the mines. For the Colmol, manufactured by The Jeffrey Manufacturing Company, Columbus, Ohio, there has been provided the largest explosionproof, totally enclosed, nonventilated, continuously rated motor Westinghouse has ever built.

This squirrel-cage motor develops 70 hp at 1180 rpm and can do 90 hp for one hour. In appearance it bears no resemblance to a conventional motor. It is a rectangular, ribbed steel box two feet square and three feet, four inches long. The frame is of cast steel with end bells of nodular iron for high resistance to shock. Roller bearings are used for the same reason. Because of restricted cooling, silicone and other high-temperature insulating materials are used throughout. The motor is equipped so it can be quickly changed to use 220- or 440-volt power as the mine location warrants.

The Colmol digs the coal and passes it back to Molveyors. These are mobile conveyor sections that are linked end to end and extend out to the main haulage ways. Beginning at the Colmol, each Molveyor passes the coal back to the next, brigade fashion. Each Molveyor is powered by a ½-hp a-c motor that is totally enclosed, nonventilated, and explosionproof. This motor makes six starts per minute and runs for 0.62 second, during which time it moves the machine five inches. Torque must be adequate to slide the machine when turning a corner. It is a high-slip, high-torque motor, but being small needs only class A insulation.

To operate the belt motion of the Molveyor is a two-hp, four-pole squirrel-cage motor similar to the one providing traction. It also is explosionproof.

Transportation



Direct-Current Aircraft Motors

Each d-c motor is only 5¼ inches in diameter and weighs 37¼ pounds, but delivers 3¾ hp at 42 000 feet. They will drive booster pumps for hydraulic-operated controls of large airplanes. They are fan cooled, have aluminum-wool flame suppressors, and radio-noise filters. Special means provide a draft of air under the commutator for cooling. The design lends itself to cooling by introducing water into the air stream if need be. With water cooling underneath the commutator, they deliver 9½ hp for short periods in aircraft service.

Aircraft Alternators Meet New Situations

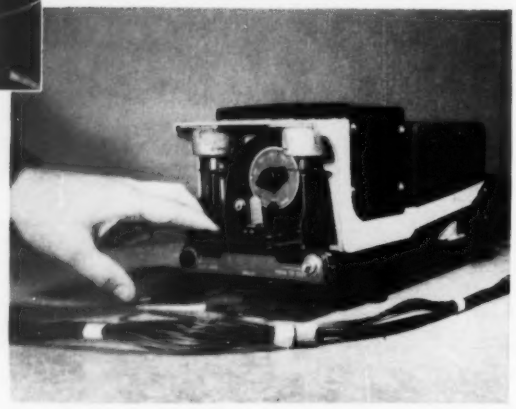
LAST YEAR saw interesting solutions to a few of the problems besetting jet aircraft alternators.

Rain Protection—One problem comes about because, with the arrival of the jet engine, the alternator has been moved up front. It is now located in the air intake, instead of behind the engine as was true with propeller aircraft. This means that air—along with any fog, snow, or rain—passes directly across the exciter, its commutator, and the alternator itself. There are no bends in the ductwork to throw out the water. Some rain water on the windings does no damage because the temperature is so high the water flashes to steam, which passes on out, carrying some of the machine's heat with it. However, water

(Right) **A-c generators used in the air intake of jet airplanes must have special provisions to protect the exciter against water swept in by rainstorms or fog. The generator is rated at 20 kva, 4000 to 8000 rpm, 120 volts, single phase. *(Bottom)* Members of a new family of three-phase, 400-cycle aircraft motors designed with special reference to simplicity of construction, and minimum weight and space.**

Carbon-pile type regulator used to control the output voltage of 30-volt, direct-current aircraft generators.

Magamp regulator for three-phase alternator.



Control and protection panel for a-c aircraft systems.

spraying on the slip rings and commutator is something else. This causes rapid fluctuations in brush drop, if indeed it does not result in reversal of exciter polarity.

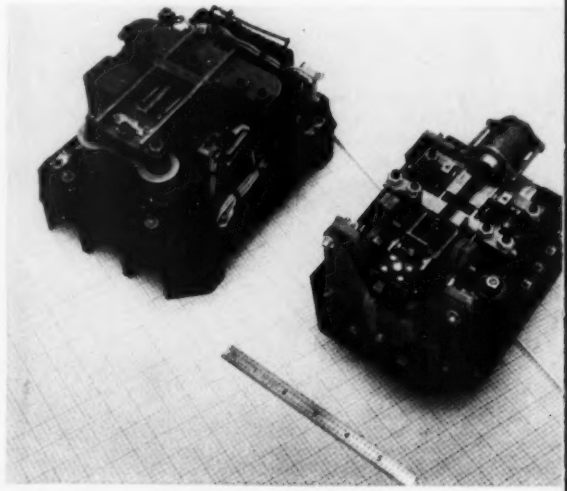
The answer is to seal off the forepart of the machine—the part containing the commutator and slip rings—and let the whoosh of air, and water if any, come in over the exciter core and flow back across the alternator and out. Baffles create enough turbulence to cool the shrouded current-collecting mechanisms.

Alternator Bearings—A 60-kv alternator rotor may lengthen by almost $\frac{1}{16}$ inch as it passes from one extreme of temperature to the other. That expansion is far more than ball bearings can absorb. It has called for various mechanical means of compensating for it—all of them complicated.

The answer is the essence of simplicity. At one end is a fixed ball bearing of the usual type. At the other end is a roller bearing. The outer race, slightly longer than the rollers, is secured to the stator, and the inner race and rolls are mounted on the rotor shaft. The rotor with the inner member of the bearing is thus free to move lengthwise in the outer race, which is part of the stator. This scheme has previously been used on railway motors.

Water-Cooling for Generators—An apparently anomalous situation is developing in cooling electrical apparatus in jet airplanes. The temperature of the incoming air may be 70 degrees below zero F, which would seem to be just dandy for cooling. Instead, however, this frigid air may heat the machine instead of cooling it. The joker here is that at jet-airplane speeds the kinetic energy added to the air is so great that its effective temperature as it impinges on the machine surfaces may be 250 degrees F.

Ordinarily an electrical designer shudders to think of water being sprayed on his product. But perhaps he may deliberately resort to it for equipment that is to ride the high-speed jets. A 400-ampere d-c generator has been modified to increase its rating to 500 amperes. The liquid, which is a mixture of water and a chemical to depress the freezing point, is introduced through the shaft at the commutator end and is sprayed on the underside of the commutator bars. Surplus liquid passes on into the rotor and outward through special passages in the core, absorbing heat and vaporizing en route.



Combination main contactors and circuit breakers for three-phase alternators and d-c generators for aircraft. The a-c unit (*left*) weighs 8½ pounds, has a continuous rating of 175 amperes, 208 volts and interrupts 3000 amperes in 0.2 second at 65 000 feet. D-c energy for its coils is rectifier supplied. The d-c unit weighs six pounds, has a continuous current rating of 500 amperes, and interrupts 4000 amperes, 30 volts at 65 000 feet.

Simplicity, Few Parts Denote A-C Aircraft Motors

SIMPLE THINGS are usually the more beautiful ones. On that basis a new family of motors for the suddenly grown-up a-c system for planes would do well in a beauty contest. These motors contain novel features of construction, all aimed to achieve the ultimate in simplicity and economy of size.

These are three-phase motors ranging from 1/30 hp to 3 hp, but their unusual construction features for mass-produced motors can be extended up to perhaps 10 hp. The four-pole motor (11 300 rpm at 400 cycles) with a four-inch diameter frame develops 2½ hp and weighs 10 pounds, and is only four inches in length, outside the brackets. The ¼-hp motor is 2½ inches in diameter and weighs 2½ pounds.

These ratings are met at all altitudes up to 50 000 feet. In spite of their small size, however, the temperature rise of these motors is small. Tested at sea-level conditions, a representative unit showed only a 12-degree-C rise at the bearings and frame and only 30 degrees C at the windings. This performance results from the manner of cooling the motor—which is totally enclosed, fan-cooled (and explosion-proof). A new type of enclosed blower with an extremely efficient blade draws far more air than normal for motors of such size. This air is driven through fins between the outside of the aluminum frame and the cover.

This frame is an aluminum extrusion—which makes possible the horizontal ribs forming the air channels—and lends itself to high production. The core consists of punchings held together by a special welding technique with the weld ground down until the entire outside diameter is smooth. It is pressed into the stator; there are no through bolts or rivets. Short-circuiting of punchings by welding is so slight that the rise in core loss cannot be detected. When the core is pressed into place the stator becomes a single piece without bolts or rivets.

The Magnetic-Amplifier Regulator for Aircraft A-C Generators Proves Itself

THE MAGNETIC amplifier has in a brief time established itself as the basis of a superior regulator for a-c generators for airplanes. Although Westinghouse introduced this device only about a year ago, experience with it on aircraft has supported the expected performance and has justified the initiation of its development into other forms. In its initial form it was applicable only to constant-speed alternators. Now the extension of magnetic amplifiers to the regulators of variable-frequency alternators and to exciter-type voltage regulators is expected.

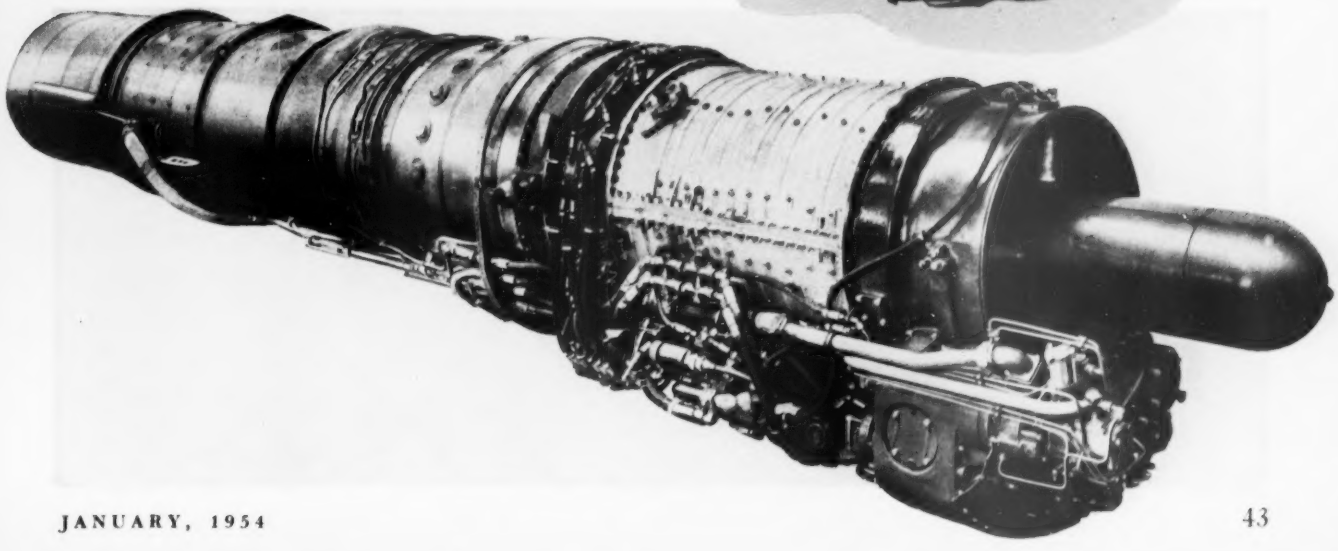
The outstanding qualities of the magnetic-amplifier regulator are that it is a completely static device and almost entirely indifferent to the wide swings in environmental conditions common in the life of airborne apparatus. Once adjusted, the performance of the Magamp regulator remains constant day after day regardless of what the plane is called on to do.

The Westinghouse form of magnetic-amplifier regulator is interchangeable physically and circuit-wise with the conventional carbon-pile regulator. Furthermore, it is used with standard existing alternators; no special windings are required on the generator nor special relays to insure fault clearing. To make certain that, on incidence of a fault, the generator voltage is maintained long enough to allow fuses to blow and isolate the faulted circuit, small current transformers in each generator lead provide a signal to the generator-field magnetic amplifier that is approximately proportional to the fault current. With this system, furthermore, fault currents are controlled so that high transient voltages do not appear after fault clearing. This avoids excessive requirements on fuses and other interrupting devices.

Control for Aircraft A-C Generator Integrated into One Panel

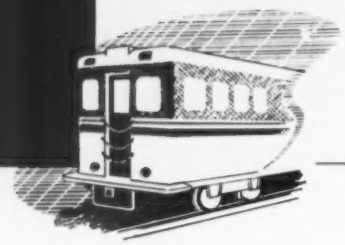
THE A-C SYSTEM is well on its way to being the predominant power supply for airplanes—although no one doubts that d-c will always be used for certain—probably the smaller—airplanes. Most new airplanes entering construction, and all

This is the *Cutlass*, equipped with two Westinghouse J46 jet engines. Below is one of the J46 engines, now in quantity production.



In a few weeks the first train of rectifier-powered cars will go into service on the New York, New Haven & Hartford Railroad. One hundred such cars are now under construction. The New Haven system is ideal for the rectifier cars because the power supply is third-rail direct current for the first 12 miles out of New York City. On this section the motors can take direct current directly from the third rail. When the single-phase section is reached at Woodlawn, a-c power is collected via pantograph, rectified, and delivered to the motors. This makes possible the use of d-c motors instead of the commutator-type a-c motor. These motors are of the same design type that has performed well in subway service for many years.

It is of interest to note that an experimental ignitron multiple-unit car has been operating regularly on the Pennsylvania Railroad out of Philadelphia for four and a half years. As of press time, the car was operating on the original rectifier tubes, and on the first igniter in each (a tube has a spare igniter).



Rectifier Cars in Service This Winter

planned for the future, are basically a-c systems, with the required d-c usually supplied by conversion. Westinghouse is producing more a-c than d-c electrical aircraft equipment.

The rapid rise of a-c systems has brought into being basic elements necessary for successful system operation. One is the panel for controlling the a-c generator. It follows the philosophy highly successful with d-c systems, namely, that of assembling on one panel the several devices necessary for control and protection of the generator.

The control panel for one three-phase generator of either narrow or wide speed range (AVP 133) weighs 12 pounds and occupies a volume of 6 by 6 by 15 3/16 inches. Many functions are served by the components within this space: a relay for opening and closing the generator field circuit when necessary; protection for either ground or line faults; generator overvoltage protection; overvoltage lockout relay; a means of indicating to the pilot or flight engineer the loss of electrical power; a relay that permits the generator to build up voltage independent of the 28-volt battery system; a means of flashing the exciter field should voltage build-up be impossible because of an accumulated commutator film or loss of residual magnetism; a transformer-rectifier unit as a source of 28-volt power for performing control functions on the panel; and provisions for checking, in the plane, the operation of protection relays. The panel employs the keyed plug-in, quickly removable construction similar to that developed for d-c systems. Other control panels are under development for different types of a-c systems such as multiple-generator systems, for aircraft that have both a-c and d-c power supplies, and for aircraft where a simplified control is acceptable.

To Enable Airplanes to See and Fly Better

THE SCIENCE of annihilating our fellow man seems to proceed along many fronts—one is the art of directing projectiles so that they and a target occupy the same position in space simultaneously. Typical of equipment used to this end is the combination search, fire control, and tail warning radar in the night-fighter jet aircraft. This plane carries a radar unit, four times more powerful than its predecessor, searches for the target and follows until the objective is relatively close. Then a second radar unit is energized and tracks the target automatically, giving the pilot computed direction and distance to the enemy craft. The feature of the equipment most comforting to the pilot, however, is that all the time he is following one target, all sides are watched by radar. Sometimes it's most useful to the pilot to know what's behind.

Transistors—The development of transistor circuits for air-borne applications has proceeded to what appears to be its limit with the presently available units. Many different types of transistor circuits have been built and successfully operated. Some of these are a transistor radio (of course), oscillators, amplifiers, multi-vibrators, and pulse generators. A transistor carrier-current intercommunication set has been built as a demonstration. A tubeless B-scope indicator has been built using 20 transistors and 12 germanium diodes.

The amount of effort being expended on transistors is limited because the present commercially available transistors fail to meet the environmental requirements of military aircraft. However, a watchful eye is being kept on any new developments, such as improved performance in the silicon and unipolar field-effect transistors, that may open the door to the improvements in air-borne electronics equipment.

Magamp Voltage Control—Another improvement in radar design involves magnetic-amplifier circuits for holding voltage constant. This is quite a trick when the variables are considered: airplane supply varies from 102 to 124 volts, at frequencies of 380 to 420 cycles per second. Furthermore, the radar load varies as much as 20 percent, depending on the phase of operation of the equipment.

A control system holds the effective filament heat to plus or minus one percent. This is done by designing the error detector to respond to rms (effective heating) voltage. The detector controls a two-stage Magamp, which in turn regu-

lates the filament supply voltage. By using magnetic amplifiers, the power-supply regulator approaches the reliability of a common transformer.

Computers Aid Autopilot Design—Automatic pilots require a lot of designing time. Large computers, such as the Westinghouse Anacom, played a major role in developing the W3A.

Fundamentally, a Westinghouse autopilot now goes through three phases of design. First, the system is completely simulated on a computer. Many of the autopilot components must be idealized, but system parameters can be determined. Second, individual components are designed and substituted in a flight simulator. Therein lies the most recent improvement—the simulator now in use at the Westinghouse Air-Arm Division has everything but wings and an engine. An electronic computer represents the aerodynamics of flight—the rest of the system is exactly that of the airplane—right down to the linkage mechanism of the pilot's controls.

The newly designed flight platform and the altitude simulator make this second phase possible. The flight platform consists of a table that rolls, pitches, and yaws just as the actual airplane does in flight. Gyroscopes that control the autopilot are mounted directly on the table.

Another Jet Engine Goes into Production

ANNOUNCEMENT was made in September that a new high-power, low-weight, turbojet aircraft engine met its 150-hour qualification test and was placed in production. This is the J46, an outgrowth of the highly successful J34, and is intended for use in high-speed fighter planes. It will be first used in the new swept-wing, tailless Chance Vought F7U-3 "Cutlass," one of the Navy's latest high-speed, carrier-based fighters. In passing the qualification test, the engine ran the equivalent of 75 000 miles, enough to circle the world at the equator three times. The J46 is 16½ feet long, not quite 3 feet in diameter, and weighs approximately 2000 pounds.

Last summer the Navy's Bureau of Aeronautics extended the allowable overhaul time for the Westinghouse J34 engine to 720 hours, an increase of 70 percent over the previous allowable time of 420 hours. This is in recognition of the excellent service record through thousands of hours of flight operation in different airplanes.

With the endeavor to attain higher speeds, it is of interest that on October 3 the "Skyray," powered by a Westinghouse J40 engine, established a new world's speed record. Four consecutive runs were made over a three-kilometer straightaway course at an average speed of 753.4 mph, which is 16 mph more than the existing record.

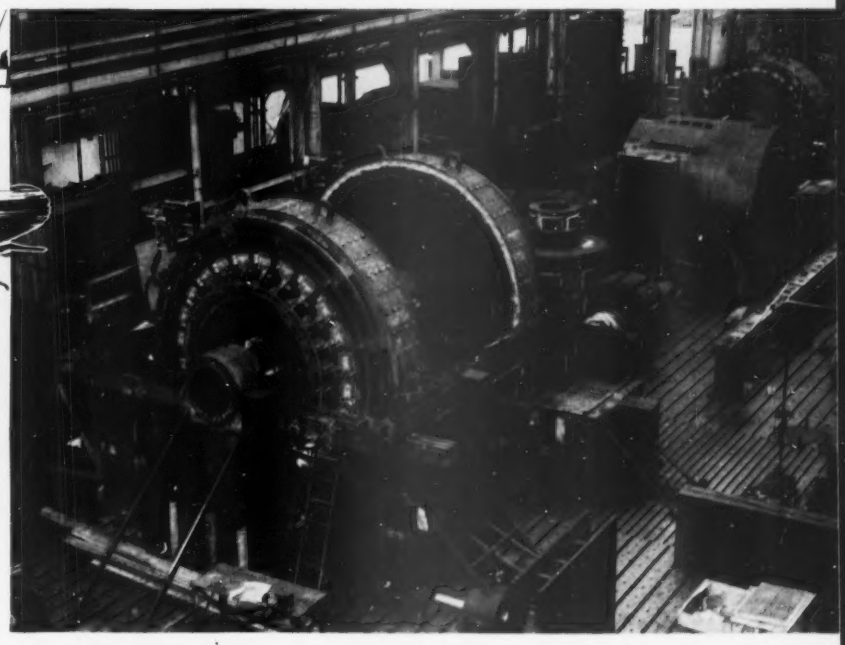
It was announced last summer that Westinghouse and Rolls-Royce, Ltd., Derby, England, signed an agreement providing for mutual technical cooperation for a period of ten years. Subject at all times to the approval of the governments of the United States and the United Kingdom, the agreement includes exchange of information in the design, development, and production of gas-turbine aero engines and a limited interchange of personnel, and, while not specifically designed as a manufacturing license agreement, this contingency is covered should it become advantageous.

The first application of the agreement is the collaboration of Rolls-Royce with Westinghouse in future development of Westinghouse jet engines.

A High-Pressure Turbine-Electric Locomotive

THE FIRST coal-burning, turbine-electric locomotive with a high-pressure, high-temperature boiler is nearing completion. This is a joint project of Baldwin-Lima-Hamilton, Babcock and Wilcox, Westinghouse, and the Norfolk and Western Railway. It is designed to develop 4500 hp from 12 motors, one on each axle. Steam is produced in a forced-draft boiler at 600 pounds pressure, 900 degrees F. A noncondensing, impulse turbine drives two d-c generators through a gear. The locomotive is expected to provide operating advantages of electric drive and be more efficient than conventional steam locomotives.

An Irresistible Force for an Immovable Object



To break up 20-foot-thick polar ice would seem to be a job for an atomic bomb. Nonetheless the Navy is building a super-husky ice breaker for the task. It will require lots of power, of course. That power will come by way of two 10 500-hp d-c motors, the largest capacity, single-armature d-c motors ever built. Each motor, which will drive a screw directly, is 15 feet 3 inches in diameter and has a four-hour current rating of 9300 amperes at 900 volts. To keep the inertia as small as possible every available design trick was employed to reduce weight compatible with high-shock strength. Power for the motors will be provided by ten diesel-driven, 1700-kw generators. The motors are shown on test.

Railway-Motor Pinion Tapered

THE MOUNTING arrangement of pinions on locomotive motors is such that the tooth contact with the mating gear is not uniform across the entire tooth face. Shaft deflection, circle deflection, and axle-bearing clearances combine to concentrate the contact at the end of the tooth face next to the motors. This concentration of contact is more pronounced on one side of the pinion tooth than on the other.

To relieve this concentration, pinion teeth now are ground with a slight taper from one end to the other. This is accomplished by an adjustment of a special machine that grinds the teeth a few thousandths of an inch narrower at the motor end than at the outboard end. To produce the slightly different tapers on the two sides of the teeth, the machine is adjusted so that a tooth section at the outboard end is offset slightly from a section at the motor end. This is done without disturbing tooth spacing or profile. The result is a compensation for natural misalignment and a more uniform tooth loading, which makes for reduced bending stress in the teeth. Because fatigue life of the gears is thereby greatly lengthened, the chance of tooth breakage while on the road is lessened.

Locomotive-Motor Regreasing

IMPROVEMENT in the stability of greases for roller bearings of locomotive motors has so improved that the recommended period for regreasing has been extended to coincide with motor overhauls. Thus, instead of having to relubricate every 30 000 miles or three months, whichever comes first, it is now 300 000 miles or three years. This means more than just the reduction of servicing labor. It means the greasing can be done when the motor is taken down for its inspection, at which time a better lubrication job is possible. Also it eliminates the chance of using the wrong kind of grease or of getting dirt into the bearings. Grease fittings are purposely omitted from the motor bearings.

A Relay Race

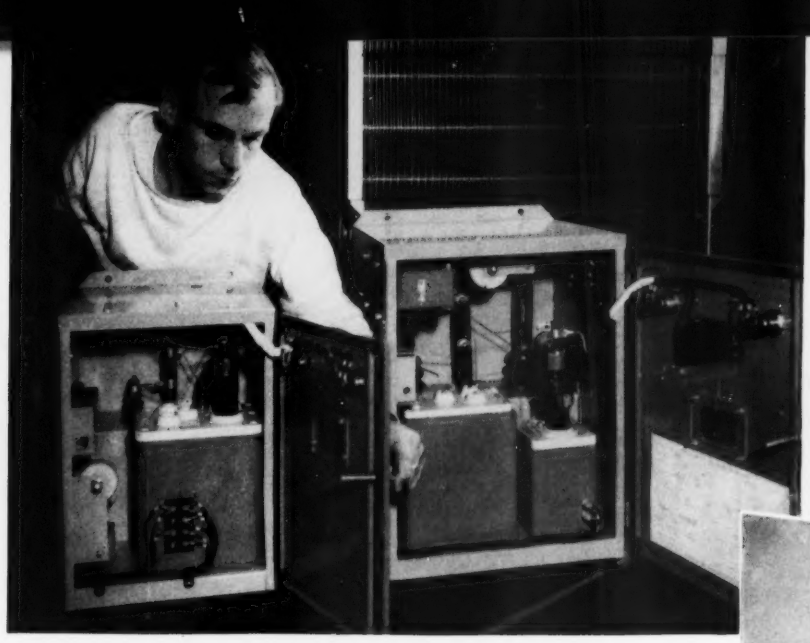
WHEN A SHORT circuit occurs in the traction-motor circuit of a diesel-electric locomotive, a race begins. The current from the main generator begins to rise at a terrific rate—approximately 500 000 amperes per second. If this current rise is allowed to continue unchecked the commutator flashes over, often causing extensive damage to the generator. The race is between the rapidly rising current and the protective relay (called an impulse relay) that senses the current rise and acts to remove excitation from the generator field either before flashover or so quickly thereafter that extensive damage is prevented. The relay designed to do this and the contactor associated with it are new in combination but old as to components. They act so quickly that the total time from start of the current rise to extinction of contactor arc is one fortieth of a second, which is short enough to prevent commutator flashover.

Laboratory tests show that the relay provides excellent protection to a generator. When the generator was short circuited repeatedly at its maximum voltage, the resulting flashes caused minor and superficial damage to brushholders and the ends of the commutator bars. Without the relay one short circuit and resulting flash under similar conditions caused sufficient damage to require extensive cleaning of the brushholders and commutator bars and replacement of the string band and some brushholder insulators.

Top photo courtesy of the Astoria Marine Construction Company.

Minesweeper Drive

When they say a minesweeper is nonmagnetic, they really mean nonmagnetic—it has to be to stay afloat. The reduction gears are nonmagnetic too. In the manufacture of reduction-gear units, generous use was made of nonmagnetic alloys. One is Discaloy, an alloy steel originally developed for high-temperature applications; it is also nonmagnetic, and has good physical properties at normal temperature. Another is Ampcoloy, an aluminum bronze capable of being heat treated to high Brinell hardness and having unusual physical properties for aluminum bronze. Stainless steel, of the nonmagnetic type, is also used. Some of the castings required for these units are the largest ever made from cast aluminum where close tolerance machining is required. Generators and motors use no iron except in the core. Frames are aluminum.



Precipitron Power Pack

New transformers make possible smaller, simpler, and better-performing power packs for Precipitron electronic air cleaners used in industrial and commercial service. Instead of using the conventional high-impedance transformer, a new unit having low-impedance and with saturable-reactor control is employed. Regulation is improved and voltages can be set at any desired value instead of in a few finite steps. Two units now serve the range of Precipitron sizes; before it took three.

Air Conditioning

Developments in Air Conditioning

ONE HAS only to glance at the air-conditioning business to see two conspicuous trends. One is the present phenomenal increase in rate of growth of the industry itself. The other is the improvement of air-cooling devices, mostly in the way of reduction of dimensions and weight.

Take the two-ton residential air-conditioning unit, for example. By comparison with the previous unit of the same rating the new one stands only one third as high (23 inches instead of 69) and is only two thirds as deep. Actually it occupies almost the same total cubic inches of space as the one-ton window unit made ten years ago. Furthermore, the components—compressor, fan, evaporator, and condenser—are arranged differently to make even better use of that space. It is made purposely flat—it is only 23 inches high—so that it can be suspended from a ceiling, and thus occupy no floor space at all, or it can be tucked away in an attic of low headroom. The unit includes a fan; it does not depend on a fan in some other part of the system for air drive. Normally the unit is operated with the fan and evaporator within it. However, if remote installation is required, these elements can be removed from the air conditioner and fitted directly into the duct-work.

The larger size cooling units—three- and five-ton—have also been made more compact for home use, but are still not small enough for ceiling suspension. The floor space occupied by each has been reduced by one third. Although this suggests a greater crowding of components, accessibility for servicing has been improved. Also the adaptability to flow directions to meet any specific home space and piping situations has been bettered.

Heat Pump—The heat pump last year moved from field trials to the production line. Both the 3- and the 5-hp heat pumps are now being produced in quantity. These are improved versions of the models that have been undergoing service tests in actual homes for about two years. One important improvement has been made in the capillary tube, which controls the refrigerant flow reversibly for both heating and cooling. Although this was already a simple capillary tube, the experimental models had three tubes while the new version does the job with only one. Elements have also been rearranged for a reduction in overall cabinet space.

Above is the five-hp size of heat pump, now in production. The two-ton home air-conditioning unit, below, is only 23 inches high.

Compressors—The trend in compressors for the larger size commercial air conditioners is to higher speed, fewer but larger cylinders—and net drop in compressor size and weight. The 75-hp compressor uses 6 instead of 16 cylinders and runs at 1200 rpm instead of 900. It weighs but 29 pounds per ton of capacity, which is exactly half the weight of the predecessor unit. By the same kind of design improvements, the

weight of a 20-hp unit has been reduced from 1350 pounds to 900. To cut down starting current, the motor has windings that permit starting in steps.

Packaged Air Conditioners—The packaged air conditioners (SU) of three- to eight-ton capacity, as are used in small shops and in offices, have been given a new dress with more pleasing appearance as the objective and with a view to greater ease of servicing. This results from the greater exposure of the equipment once the front panels are removed.

Simplified Washers for Industrial Precipitron

THE LARGE installations of Precipitron air cleaners, as in steel mills, have an automatic arrangement for washing the collected dirt from the plates and reapplying adhesive. They are arranged to clean one section of the Precipitron at a time so the whole unit does not have to be shut down during washing. This is fine, but it is a de luxe, expensive system.

Many industrial or commercial situations can do very well with a system that is not fully automatic and can stand a shutdown of the air-cleaning system for a few minutes at night or over a weekend. For such, a simple cleaning and adhesive-application system is now available. A vertical pipe (header) with water and adhesive nozzles is motor driven on a simple track across the face of the air-inlet side of the cells. The operator presses buttons that cause the header to scan the cells, first with jets of water, and then with adhesive. Even for a bank of cells 12 feet high and 15 feet wide, the complete washing operation takes but 20 minutes.

Precipitron Air Cleaner Becomes Smaller, Easier to Install

THE PRECIPITRON electronic air-cleaning unit has undergone a major transformation. By new designs of components and their rearrangement, its size has been reduced to one third; the floor space it occupies has been reduced to zero; and the cost of installing it has been cut materially. The unit can be mounted against the ceiling, in either of two positions. No special electrical wiring is required; the Precipitron plugs into a 120-volt, 60-cycle convenience outlet just like a toaster. The water connections for washing can be lengths of ordinary garden hose. Hence no electrician or plumber is needed for installation. Because it can be mounted against the ceiling in either of two positions, or on the floor if desired, the construction of duct work is greatly simplified.

Periodic cleaning is accomplished by opening a switch to isolate the unit electrically, and turning on the water. After a few minutes the water is turned off and the energizing switch again closed.

Instead of the single rating of 1200 cfm previously available, two sizes are now built, one for 1000 cfm, the other for 2000, which suit homes of different size.

More Efficient Forced-Draft Fan

AN IMPORTANT gain in efficiency of induced draft fans has been made, not, as one might guess, by a more effective blade shape, but in the design of fan housing. By changing the shape of the scroll case the energy loss has been cut by a third. Where these fans run continuously, this energy economy is especially important.

Lamps and Lighting

1

Mercury Lamps Continue a Fast Development Pace

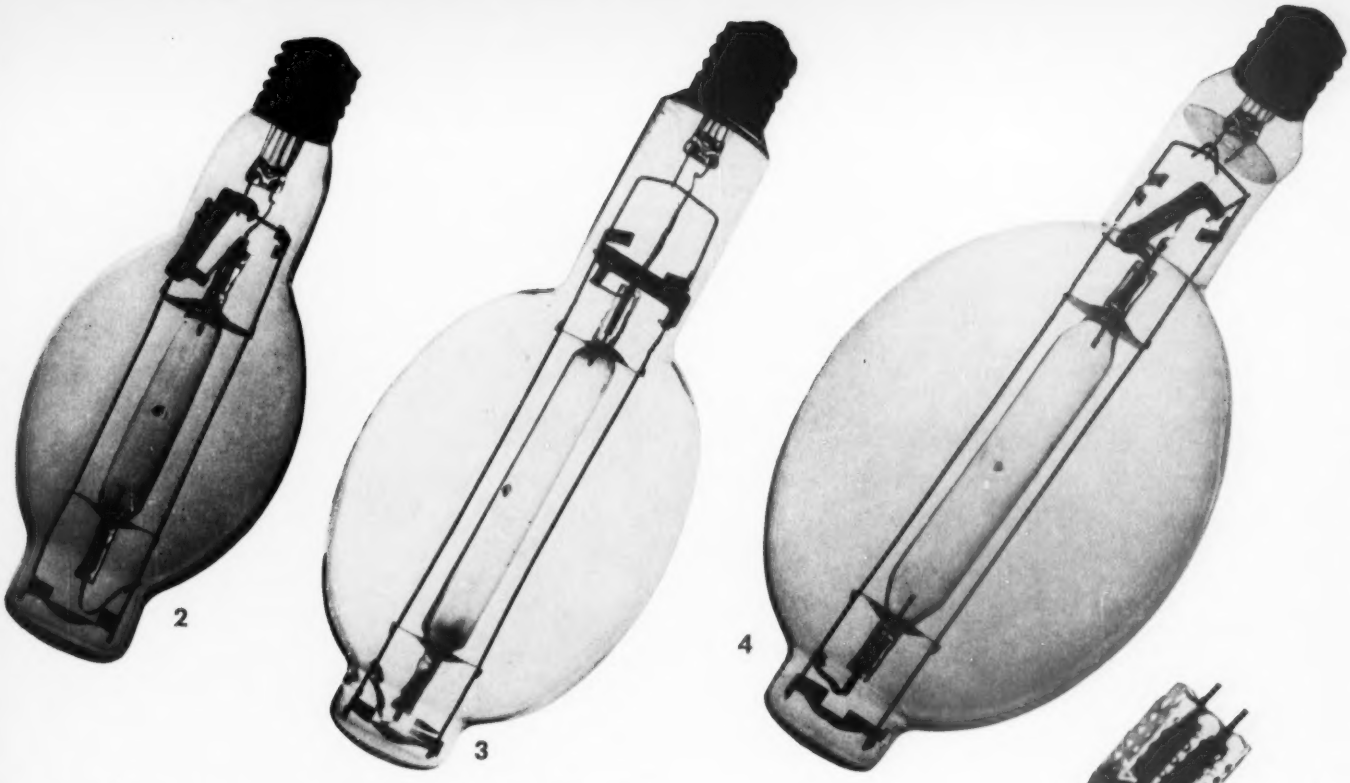
MANY DEVELOPMENTS were registered in the family of mercury-vapor lamps, which is now growing in use at a much more rapid rate than either incandescent or fluorescent lamps.

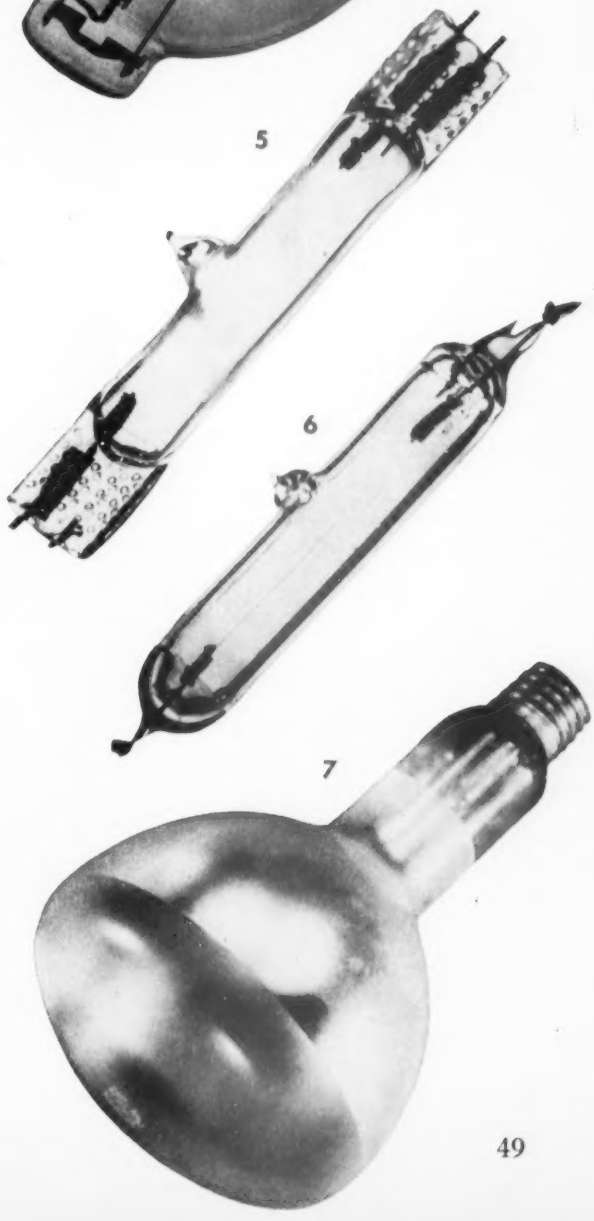
More Varieties—For one thing it is a growing family. A 700-watt size in both straight mercury and in fluorescent-mercury (color corrected) has been added between the older 400-watt unit and the still relatively new 1000-watt size.

There is a new high-voltage line of lamps (265 arc volts) in both mercury and fluorescent-mercury types. In addition to this 700-watt size there are new 400- and 1000-watt lamps. These lamps fit in with the growing use of 480-volt circuits. They have several advantages: the lumen output inherently holds up well throughout life; they can be operated from 480-volt lines on simple, low-cost, choke-type ballasts; and they start in cold weather with no more voltage than would be used for indoor operations.

Keeping the Light Output Up—Improvements have been made in lamp design that raise the curve of lumen output during life. Rated average life has been increased. The most used sizes are now rated 6000 hours' average life—several times the life of incandescent lamps.

A recent change in cathode construction improves lumen maintenance significantly. Depreciation of output mostly comes from the slow evaporation of the cathode materials and their condensation on the quartz walls. Thorium, incorporated into the cathode to facilitate starting, is the principal





1—**A reflector-type mercury-vapor lamp.** *2, 3, 4*—**The 400-, 700- and 1000-watt mercury lamps, respectively.** *5, 6*—**Mercury-arc tubes showing new and old electrode-seal construction.** *7*—**One of the recently introduced 550-watt incandescent reflector lamps.**

material deposited on the bulb wall. Now the thorium is separated from the main burning electrode of tungsten; it is moved back into the neck of the quartz arc tube. There the temperature is lower, so the thorium—separated from the burning electrode—does not evaporate as rapidly. Also the thorium that does boil off is more likely to condense on the neck of the arc tube where it does not block the light.

Mercury-vapor lamps have been improved by a new manner of bringing the molybdenum-ribbon conductors into the arc tube. The old way was to soften an evacuated quartz tube and flow it around the thin metal strips placed inside the tube. Now a sandwich is made with mechanical pressure to force the quartz tightly around the metal in between. The quartz tube is heated on both sides by gas flame until the softening point is reached. Then, with the heat turned off, the gas-jet nozzles are forced under some pressure against the soft quartz, welding the sandwich solidly as one piece.

Short-Arc Mercury Lamps—The short-arc mercury lamp is also growing in popularity. This lamp, with its arc confined to the small space in the gap between two narrowly separated electrodes, provides a concentrated light source of high intensity and high efficiency. These qualities are giving it preference in many photochemical operations, ceiling projectors, and searchlights.

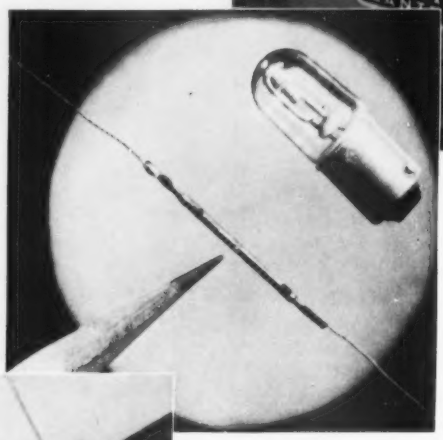
A better way has been found to make electrodes for short-arc lamps. Electrodes have been machined out of solid tungsten—which isn't easy. Now a standard piece of tungsten rod is processed to allow a ball-shaped terminus to be formed. Then behind this rounded end are wound several layers of tungsten wire, which provide a large radiating surface. The total result is a smaller electrode, with less material. Not only is electrode life lengthened by a factor of three or four, but the light output holds up better.

Lamps the Size of a Pencil Lead

A NEW LIGHT source is smaller than the head of a pin. It is a sub-miniature, neon-argon glow lamp and has a special job to do. Fifty of them are laid out side by side in a total linear space of three inches, in front of a moving strip of 35-mm film, for recording events in a laboratory experiment where space is scant. This "lamp" is a slender glass tube 0.05 inch in outside diameter and 1¼ inches long. The glow, when a 110-volt, d-c potential is impressed across it, is formed in a gap 1-mm (1/25 inch) long between 0.03-inch-diameter Kovar electrodes in the glass cylinder. This lamp is a contender for, if not the holder of the title of the "world's tiniest lamp."

The lamp and a tiny resistance in series with it to limit the current—½ milliampere—draw only 1/20 of a watt. The energy in the glow is but 1/30 of a watt. One of the problems in making such a tiny glow lamp is that the volume of gas is so small that any slight contaminant has a large effect. Even the gas contained in the bit of glass pinched off the end when the lamp is sealed must be considered.

Gigantic by comparison but still also quite small is another new glow lamp—a miniature high-brightness glow lamp—also for recording events on film in a laboratory study. Instead of the sizable halo of light around the cathode that characterizes most glow tubes, this lamp has a concentrated spot 0.065 inch across. The lamp operates through a resistance on 110 volts d-c and can be pulsed at 15 milliamperes. To achieve the concentration of light, an entirely new form of electrode controls the glow discharge and limits it to the top surface. For quick starting, a small amount of radioactive material is included.



Above: A new hand lantern uses a new prefocused bulb and either a 6-volt battery or eight 1½-volt cells. *Left:* The pencil points to the gap in the smallest glow lamp. Beside it is a concentrated-spot glow lamp. *Lower left:* A concentric-ring luminaire makes good use of the silvered-bowl lamp. It can be suspended from an inclined surface.

Fluorescent Lamps

FLUORESCENT LAMPS have been made more versatile and with longer life. The Slimline variety (T-12) in the four-, six-, and eight-foot lengths can now be operated at any of three degrees of brightness, depending on which ballast is selected. New cathodes make it possible to operate the lamps at loadings as low as 200 milliamperes and as high as 600.

Fluorescent lamps are moving in a serious way into a field relatively new for them: outdoor service. A new six-foot lamp has been developed especially for street lighting, tunnels, underpasses, semienclosed garages and warehouses. It is the rapid-start variety and operates at high loading, which gives good performance in cold weather. Companion developments are shorter versions of the instant-start lamp—in five lengths down to 24 inches—for sign lighting.

Fluorescent-lamp life ratings have been stepped up from 6000 to 7500 hours for T-12 Slimline and from 4000 to 6000 hours for the low-brightness T-17 40-watt fluorescent lamp. Better electrodes, phosphors and techniques have raised the efficiency at the end of rated life from 75 percent to 80 percent of initial output.

New Fixtures for Silvered-Bowl Lamps

NEW DESIGNS of concentric-ring luminaires are announced for silvered-bowl incandescent lamps, which have been increasing in popularity. To make an indirect-lighting unit with this lamp, three vertical rings are placed concentric with

New flash bulbs ease the photographer's space problem.

Short-arc mercury lamps now have longer service life.

the axis of the lamp to shield the bright neck of the lamps. With this arrangement the light is directed by the reflector in the base of the lamp to the ceiling without the light source being visible at any normal viewing angle. The shielding ring surfaces are vertical and, therefore, dirt and dust collection are minimized. Maintenance becomes essentially nil. The reflector inside the lamp is permanently clean. Because the bottom of the lamp is exposed, a burned-out lamp can be changed from the floor by a suction cup device on the end of a long handle.

These fixtures are made for lamps in all ratings from 200 to 1000 watts. Also, because modern construction sometimes calls for sloping ceilings, these luminaires have 45-degree universal swivels at the ceiling canopy. The hanger is designed for easy attachment to outlet box screws or to a stud.

Developments in Incandescent Lamps

REFLECTOR LAMPS continue along the straight-line portion of the popularity curve. The advantages of permanence of light output from built-in reflectors and the lack of necessity for cleaning cause them to be used in more and more applications. To keep up with the demands, last year two larger sizes were developed—550 and 800 watts in both the wide-beam standard voltage and medium-beam varieties.

Reflector lamps are also developed in colors—red, blue, yellow, pink, and green. This makes auxiliary color screens unnecessary—a desirable feature in store windows and other places where colored lamps are used extensively.

A development was also concluded last year to improve the unlighted appearance of incandescent lamps. Ceramic-coated lamps are used in large numbers on the marquees of theaters. The ceramic coatings that have been used tend to mottle with age. This doesn't show when the lamp is lighted and doesn't affect the lamp's performance, but theater managers don't like the "measle" effect in the daytime. A change in the formulas of the ceramic coatings and a change in firing procedures now enables lamps to retain their sleek appearance until they burn out.

The developments begun several years ago to make incandescent lamps smaller (the coiled-coil filament helps to make this possible) continued last year with the 200-watt variety. This lamp is now $6\frac{15}{16}$ inches long instead of $8\frac{1}{16}$, and $3\frac{1}{8}$ inches in diameter instead of $3\frac{3}{4}$ inches. This reduction in size now makes it possible to use a 200-watt lamp in many places where formerly only a 150-watt lamp could be used.

Lamps for the Photographer

A PHOTOGRAPHER never has enough pocket space for all his camera accessories and photoflash lamps. Available is a new, smaller flash bulb. Designated as No. 8, it produces only slightly less light than the much bulkier No. 5. A package of a dozen easily slips into a side coat pocket. The new photoflash lamps can be fired even when batteries are weak. This is made possible by smaller diameter tungsten ignition wire. The new wire is but 0.0007 inch in diameter, much smaller than a human hair. A mile of it weighs less than a third of an ounce. Wire this small is obviously difficult to draw, spool, and handle—but it does enable lamps to flash at lower voltages.

Fluorescents Go Underground

THE EFFORT to do something about the traffic problem is gaining momentum. With it comes more work for illumination engineers. The number of tunnels and underpasses on the new super-highways and open multideck parking garages are increasing and demand high-grade illumination.

The fluorescent lamp is ideal for this work because it lends itself to the long lines of light these and similar applications call for. The Boqueron Tunnel near Caracas, Venezuela, is an example. In this modern underground traffic system two 6-foot Slimline fluorescent lamps were mounted in series inside a 12-foot Pyrex glass tube. For replacement or cleaning, each tube unit can be taken down as a capsule and another inserted. The light output can be adjusted in intensity by a saturable reactor. During daylight hours a higher intensity is desirable so as to lessen the difference as a driver enters or leaves the underground. The reverse is true at night.

In the hood of each street lamp is a photoelectric control to turn it on and off. The control employs only long-life devices—not vacuum-tube amplifiers.

The new floodlight for sports areas has special features to make it weather tight. The fixture can be swung back to permit lamping from the rear, after which it can be returned to its focused position.

Certain situations in our growing society—some of them new ones—are calling for much higher levels of lighting. Among these are wide boulevards that are becoming "White-way" suburban shopping centers that now are undergoing phenomenal growth, and the boardwalks of many resort cities. Thereis a trend to illuminate these areas with street-lighting units.

Fortunately the means are recently at hand to light brightly these large areas. These are the mercury-vapor lamps and, particularly, the larger sizes of fluorescent-mercury (color-corrected) lamps. The luminaire is patterned after the graceful and highly successful fixture (OV-20) developed a few years ago to utilize the 400-watt mercury lamp. The new size (OV-60) accommodates the 700- or 1000-watt mercury or fluorescent mercury. It is designed specifically to take these large sources and provide a uniform distribution on boulevards up to 125 feet wide. It is particularly intended to provide high levels of illumination. It is unique in that, instead of being mounted with its axis horizontal, it is tilted 15 degrees upward to obtain high candlepower across the street. Basically all light control is accomplished by the reflector and tilt with only a varied diffusion pattern in the globe.

A new type of fluorescent tunnel-lighting unit is a six-foot fixture of ribbed translucent plastic that will accept either one or two standard Slimline lamps or 1000-ma rapid-start lamps. With the latter lamp, because of the high current loading and close confinement, the unit produces as much or more illumination at temperatures down to −20 degrees F as at 80 degrees F. The unit can be started at −20 degrees F. Older fluorescent tunnel luminaires, using conventional lamps, suffered a substantial reduction in light output at the lower temperatures.

Using Light to Control Light

ALTHOUGH photoelectric devices have been used for many years in this country and elsewhere to control street lights, they have always been plagued with more than their share of troubles. Consisting always of somewhat elaborate vacuum-tube amplifier circuits, and subject to rugged outdoor conditions and traffic vibrations, the frequency of maintenance calls made them impractical.

For the first time in this country a much simplified device has been developed for individual control of our neighborhood street lights. Eliminating all vacuum-tube amplifiers, the new control uses a small number of inherently long-lived resistors and capacitors and a small neon glow tube controlling a relaying circuit and actuated by a photoelectric tube. A bridge-type circuit charges a capacitor to a variable potential, depending upon the amount of light falling on the photoelectric tube. When that potential reaches a predetermined value, it triggers the glow tube, thus discharging the capacitor through the tube. A sensitive polarized relay coil closes or opens contacts controlling the street lights. In addition the new circuit has the valuable advantage of an inherent time delay to provide "anti-hunting" characteristics so that repeated cycling cannot occur.

Ventilated Lighting Fixtures for Low-Bays

THE GREATEST boon to the industrial-plant lighting maintenance man in many a year has been the development of ventilated hoods for large lighting units. Holes placed in the neck of the deep-bowl reflectors allow dust-laden air sweeping up past the hot lamp to pass on out at the neck of the fixture instead of having it curve downward along the inner surface of the reflector to escape at the bottom. In so doing the dirt collects on the reflector. In a typical factory, the total output of a unit was reduced by 30 percent in 1000 burning hours while the output of a ventilated fixture alongside it deteriorated less than one half that amount.

Last year these pages spoke of the developments of ventilated high-wattage aluminum fixtures for high-bay service. These met with instant success. Now these features have been applied to porcelain-enameled fixtures used for greater diffusion of light in low-bay plants.

Radio, X-ray

Radio Transmitters Undergo Electronic Simplification

NAVY SHIPBOARD radio transmitters are undergoing a large-scale simplification. In War II, Westinghouse provided to the Navy hundreds of simple, rugged, and extremely reliable transmitters. They contained but 14 tubes total; the oscillator, for example, had only one. However, many automatic features were absent. It had many manual controls, requiring some training on the part of the operator. The war over, the Navy undertook to modernize this basic transmitter. It would be nice to add automatic controls, to make it easier for the inexperienced operator to use. It would also be nice to have automatic tuning. Sure, the designer could do each of these things! It took more circuits, more tubes, though. All this was done—whereupon the Navy found it had a beautifully performing set, simple to operate. But the set was now so complex that more experienced servicing was required than was saved in operator training. A one-tube oscillator had, for example, grown to one of 59 tubes.

A recent design of transmitter has been put through a detubing, circuit simplification, and overhauling program. The results are remarkable. With no sacrifice in performance, a set that required 93 tubes of 17 different types now uses but 32 tubes of 5 different types—and operation is possible if all but 8 tubes fail. The saving is not in tubes alone, but also in sockets, wire, switches, and relays. Advantage is taken of the new ferrite cores that permit amplifier circuits to cover a 20-to-1 frequency range without band switching.

Highlights of Electronic-Tube Activities

IF THE PHENOMENAL rise in magnetic-amplifier developments and applications suggests to anyone a lessening of electronic-tube activity, the conclusion is completely erroneous. The need for new tubes and better tubes is just as great as ever—perhaps more so. And engineers are providing them, as the following sampling indicates.

Bigger but Shorter Picture Tubes—Television picture tubes have been getting bigger. Some in the industry believe that the new 24-inch sets appearing on the market will soon displace in popularity the 21-inch set, just as the 21-inch set has the 17, and as the 17 did the smaller ones before it but a few years ago. Everyone likes the bigger picture—but the housewife doesn't like the larger cabinet required by the longer picture tube because it takes up too much of the living-room space.

But this time we can have the sweet without the bitter. Because of a development by the Corning Glass Works engineers and Westinghouse television-tube engineers, a 24-inch tube is no longer than the older 21-inch tube. The angle of the cone back to the neck where the cathode-ray gun is located—or more precisely the angle of sweep of the cathode-ray beam—is increased to 90 degrees from 70 (a few years ago it was 55 degrees). This requires relatively minor circuit modifications.

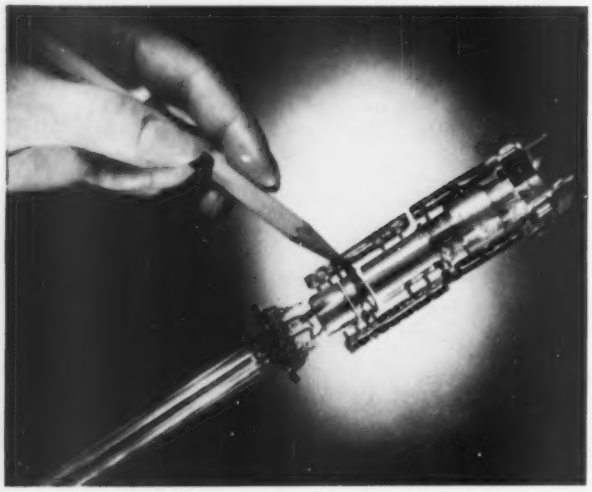
In keeping with this trend a new 21-inch, 90-degree deflection picture tube has been designed that is three inches shorter than the present 21-inch, 70-degree deflection tube,

yet gives a picture area that is 13 square inches larger than any previous 21-inch tube.

Sharper TV Picture Beams—Where TV receivers are relatively distant from the transmitters, or where the received signal is weak, picture quality is degraded by "snow." Snow is caused by electrical interference picked up or generated in the TV receiver and appears as a random pattern of white dots in the picture. To minimize the effective size of the snow particles and to obtain a sharper-focus picture tube, an extensive study has been made of the cathode-ray-tube, electrostatic-focus electron gun.

Calculations showed that the electron beam was being focused in that part of the electron gun where only acceleration should occur. The strength of this unwanted electron-lens action was affected by changes in tube operating voltages and beam currents (picture brightness) and produced a larger spot size, which decreases picture definition.

Because tube operating voltages vary widely among receivers made by different manufacturers, the principal electron lens in the electrostatic focus gun had to be matched to the receiver for best tube performance. This meant that the electron gun had to be changed to match the particular operating conditions of the receiver; in other words, tubes were not interchangeable in different sets.

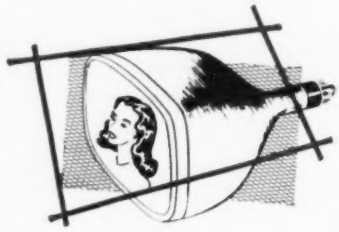


A new TV-tube gun reduces "snow" when signals are weak.

By minimizing the focusing action of the unwanted lens a new electrostatic focus gun gives complete interchangeability, smaller spot size, considerably reduced "snow" particle size, and picture resolution equal to or better than the magnetic-focus type tubes previously considered the performance standard for the industry.

Furthermore, deflection defocusing in the new 90-degree deflection 21-inch and 24-inch rectangular tubes is considerably reduced by use of this new electrostatic focus gun when compared with the standard magnetic-focus gun. To the viewer this means sharp picture detail out to the extreme edges of the tube which cannot be realized with the magnetic-focus gun.

New TV Receiver Tube—The number of different kinds of radio and TV receiver tubes runs into the hundreds. Why, one might ask, are engineers continuing to sit up nights, figuratively, to develop new ones? Well, here is a situation, typical of the many continually arising, that calls for a new tube. In TV sets it is the job of a tube known as the deflection amplifier to drive the cathode-ray beam 15 750 trips per second across the screen. The job wasn't too difficult when TV picture tubes were smaller. In the case of a 12-inch tube, for example, that meant a sweep amplifier tube that could force the beam to swing back and forth through a deflection angle of 50 to 55 degrees. As the diameter of the screen was raised, the beam deflection angle was increased, first to 70 degrees, then to 90 degrees to keep the length of the picture tube as reasonable as possible.



Simultaneously, to gain picture brightness, the anode voltage was greatly increased, from 8 kv for the 12-inch tube to 18 to 20 kv for the current 21- and 24-inch tubes. As the power required to deflect the beam depends on the anode voltage, a power increase is required of the sweep amplifier.

Why not just build a bigger tube? It isn't that easy. For reasons of space and marketing standards the tube must be contained in a receiver-tube base and overall dimensions. And already the deflection amplifier tube employs the largest receiver-tube "frame" size.

To get the needed larger rating Westinghouse receiver-tube engineers have started over on the tube, doing everything they can think of to pack more amplifier inside the glass. It called for larger elements, higher voltage ratings for parts, new grid materials to get higher dissipation, and special techniques to reduce the Barkhausen-Kurz oscillation in the tubes that causes the unwelcome black line on the screen.

Semiconductors—The rising young group of devices known generally as semiconductors, including germanium diodes and transistors, might appear to be potentially deadly rivals of vacuum tubes. In a sense they probably will be rivals of tubes; undoubtedly many tasks now done with tubes will eventually be done with semiconductor devices. But for several years any large-scale replacement of tubes in radio and TV sets by them is likely to be slight. More immediate applications are to be found in computers, various control circuits, and in small portable equipment such as hearing aids where size is important.

Germanium diode and transistor development is still in the earliest stages. But that development is being aggressively pushed, mostly in the direction to extend the power capability, increase the upper limits of frequency, and to do something about the troublesome noise seemingly inherent in semiconductors. However, by year's end Westinghouse engineers had brought to the commercial stage an even dozen types of germanium diodes, two types of point-contact (n-type) transistors, and one junction-type transistor.

Better Tubes for High-Speed X-ray Studies—About ten years ago a device called the Micronex was developed to take fast x-ray pictures—down around a millionth of a second. This has proved to be an extremely valuable research tool, particularly in the field of ballistics and explosives. But when the tubes are overloaded so as to give exposures as short as one tenth microsecond, they can last for perhaps only ten exposures. This makes picture taking pretty expensive, considering that a tube costs about $900.

A recent development has produced a metal tube with

two or three times improvement in life for 0.1-microsecond use. Now several hundred exposures are possible. More important the focal spot is smaller by a factor of four, which gives better definition, a quality of utmost value in studies of explosives. This is accomplished by use of a smaller target. Reliability is improved, which is important because the set-up for each exposure is costly and time consuming. These tubes are now being used in circuits capable of discharging the stored energy from capacitors through the tube in one tenth of a microsecond.

The Image Amplifier in Movies and TV

THE YEAR 1953 was a significant one in the life of the image amplifier. This was the year in which commercial models of this bright-image fluoroscope became available. Thus marked the culmination of a decade of development, by which the image seen by the diagnostician is at least 200 times brighter than that on the conventional fluoroscope screen. Considering the many, and often disheartening, difficulties that lay along the way in the production of consistent, high-amplification tubes, the attainment of commercial models is a significant milestone in itself. Other things of general and technical interest occurred too.

The image amplifier, for one day last April, became a television star. It was the means by which thousands in their homes saw the beating of a human heart and glimpsed other organs just as the radiologist views them. Only the super-bright image, which brings out great detail, made this possible with safety to the patient.

While this was something of a dramatic demonstration, plans are under way to put the image amplifier on television for a more serious purpose—medical-student instruction. With present extremely weak fluoroscopic images it is impossible to give class instruction from "life." The plan now under consideration is to televise the picture produced on the screen of the image amplifier to a number of medical classroom receivers. Because this will be closed-circuit television, more lines than the broadcast standard will be scanned per inch—giving more detail.

The image amplifier has gone into the movies too. It has been arranged with a special lens system and a special 16-mm movie camera so that the doctor can record the action, say, of the heart or the duodenum for several seconds. Besides being a more fruitful mode of diagnosis, it spares the patient a long-time exposure to x-rays.

In its present commercial form the image amplifier is associated with the spot-film device. This is a mechanism by which, when the fluoroscopist sees something he wishes to record, a film holder is advanced quickly by a system of levers to that area and the exposure made.

The image amplifier also became, last year, a traveler. One of the first commercial models made the trip to Copenhagen, Denmark for demonstration before the International Congress of Radiologists—the most important convention of this branch of the medical profession.

It also has taken to the highway. A large trailer—such as is used for mobile tuberculosis survey units—has been fitted with an image amplifier and is on tour to the major cities of the United States to give doctors a firsthand chance to see what it can do. Taking x-ray apparatus to the doctor or clinic for study is in itself a new idea.

Medical men are coming forward with jobs for the image amplifier not contemplated in the earlier stages of its development. It appears that it may have an important function in connection with polio epidemics. One group of doctors is using it to observe the state of a polio patient's lungs to determine whether he should be given the assistance of the iron lung—a step that must be taken quickly.

Gear Drives for Submarine Radar

The gear-drive assembly for a submarine radar antenna must be a precision device—the Synchrotie motors that indicate antenna position and guide the submarine to its quarry are a part of this drive. A new submarine radar gear unit drives two Synchroties and the antenna from a composite set of gears—replacing three independent units in the previous design. Backlash between the Synchroties and radar shaft is limited to not more than a quarter of a degree. Case-hardened gearing is used. The radar shaft and exposed hardware are made from stainless steel.

Appliances

Engineering Contributions to the Home

ONE OF THE greatest advances in cooking since man stopped eating his food raw came last year. A strong statement, but one with foundation. It is automatically controlled cooking. Put, say, a kettle of potatoes in water on the electric range, and set the control to "Boil." Then—come telephone call, a visitor or some other distraction—the electronic control on the range takes over. Even if the pot should boil dry the control prevents the rise in temperature that would carbonize the food, blacken the pot, or do even worse damage. Smoke, odor of burned food, the difficult-to-clean vessel are avoided.

This incredible performance comes about by a device that is incredibly small. It is a thermistor of fly-speck size. It is composed of sintered oxides that have extraordinarily steep negative coefficient of resistance, which means to say that unlike metals, the electrical resistance greatly increases as temperature rises. The resistance is 100 000 ohms at room temperature; 7000 ohms at 204 degrees; and 350 ohms at 450 degrees. This enables it to sense extremely small temperature changes and through amplifiers actuate controls.

The thermistor is embedded in a small button slightly smaller than a dime. This button is supported by a silicone-rubber ring in a small cup, which in turn is mounted in the center of the electric-range heating element. By spring pressure the button is held firmly against the bottom of the vessel, enabling the thermistor to sense accurately its temperature. A small variation in temperature makes a great change in the microamperes through the thermistor. This signal is fed to a bridge circuit and electronic amplifier, concluding with a current ample to control the range-element switch.

New cooking abilities increase usefulness of the deep-fat fryer.

The new table-high water heater has plumbing connections at the top, which reduces installation labor. Also it has more capacity.

The electronic control can be set for any of the three basic cooking operations—warming, boiling, and frying. By cycling the element on and off, the preselected temperature at the thermistor, in either warming or frying operation, is held within ± one half degree. In the boiling range, where the temperature does not change until all water is evaporated, the control stands by to prevent a temperature rise above 235 degrees after all water has turned to steam.

Infinite Heat from a Single Range Coil—Electric-range elements are usually in two sections, with three terminals. This gives five possible combinations of connections or a choice of five heats. There has been recently developed a single-coil range element with only two terminals—but an infinite number of heats. In series with the element is a heater in intimate contact with one member of a thermostat. The distance the thermostat arm must move to make contact is controlled by the heat dial, which has the usual five definite click-position settings. However, the dial can also be set at any intermediate position, if the cook wishes to be more precise. Because the control is now sensitive to current, it automatically compensates for line-voltage variations. Each heat setting is independent of line voltage, which is not so with conventional elements. Because the heater is a single coil and all of it is in service, heat distribution is

better than with conventional two-section heating elements.

Thirty-Inch Electric Range—Electric ranges are generally built in either the full or common size of between 38 and 42 inch widths or the apartment-house size of about 20 inches. A 30-inch range might seem to be just an in-between variation. But the acceptance last year of a 30-inch range indicates it is something more than that. It is in part due to certain technical features. The oven, for example, is 24 inches wide—seven inches wider than it is on the 40-inch model. The oven, while bigger, is even more efficient because more insulation is packed around it. (The heat efficiency of an oven is dependent mostly on the insulation and only slightly on internal volume.) The range is big enough to retain some top-surface working area and almost all of the control and other features hitherto found on only the large de luxe models.

Cook-N-Fryer—The number of specialized cooking devices continues to increase. The most recent one is a device for deep-fat frying. This one, which started out to be almost exclusively a device for frying foods in a deep bath of fat, is now diversifying, to take to itself many other cooking tasks. The Cook-N-Fryer is made bowl shaped. This provides the maximum hot-fat surface area (most frying foods float) for a given amount of fat and also provides a larger volume of space above the oil surface for the foaming that results when frying moisture-rich foods like potatoes. The rounded bottom cuts out the square corners, which have no cooking value and are hard to clean. The Cook-N-Fryer is given an accurate wide-range thermostat that enables it to be used for many other food preparation operations, such as warming soups, cooking chili, and even for popping corn.

Portable Dishwasher—One interesting new kitchen appliance comes about by chance. When it comes to an electric dishwasher there is nothing like a demonstration in the housewife's own kitchen. To make this possible a number of standard Westinghouse dishwashers were mounted on casters and given hose connections for easy attachment to the faucet and for draining to the sink. Such a unit can be wheeled into a kitchen for a trial. Then, somewhat to everyone's surprise, some people wanted to buy the demonstration units instead of the permanently installed variety. The reason: people living in rented houses are reluctant to make permanent installation of a dishwasher and others anticipate building their own home; when they move, they can take the dishwasher just as they do the furniture. Then, if they wish, in the new location the casters and hose can be removed. A standard, permanently mounted dishwasher results.

A 30-inch wide range is smaller but has big-range features.

A metal-cabinet television set combines beauty with low cost.

Automatic Processes Save Time, Make Better Refrigerators

WHEN THE first automatic factory arrives it will not be because someone went out and built one from scratch. Instead, it will be because some existing plant making a commonplace product has evolved into it. In many, many factories several process steps are being combined and placed under full machine control, leaving manual operations between these automatized sections. When these manual links have been removed, the automatic factory is here.

An excellent example of such evolution has recently been displayed in refrigerator manufacture. First, we should point out that very few mechanical devices match the domestic refrigerator in its requirement for dryness. In the drying of an assembled motor, compressor, evaporator, tubing, and con-

New Dehumidifier Is Also a Heater

The dehumidifier became a success overnight when introduced about two years ago. Now it has two jobs to do. When the humid season has passed, it can be used as a space heater for a room or basement area. A 1300-watt heater element has been added, enabling the dehumidifier blower to drive the heat into the room. Thus the unit becomes a supplemental room heater in mild-climate areas on cool days, at the beginning or end of the regular heating season. Also the arrangement of the compressor, motor, blower, and evaporator has been changed with an economy of space that reduces the overall size of the unit appreciably. The water squeezed out of the air is now delivered to a specially shaped, flat container that fastens to the back of the dehumidifier. The new container can be removed for emptying without spilling, even when full. A trap automatically prevents water from dripping onto the floor during the few seconds needed to empty the container.

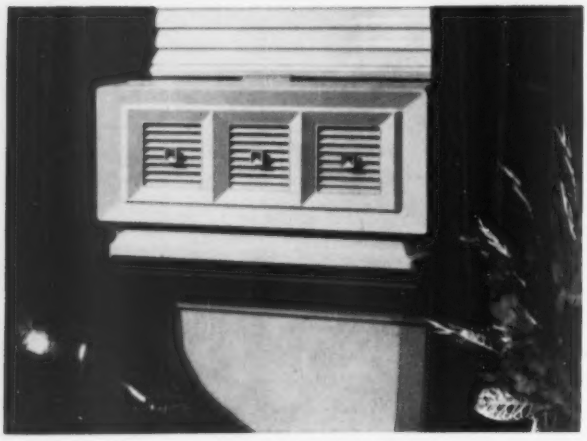
trols several spoonfuls of water may be removed on a humid day. But if one half milligram of water—that's a drop smaller than the head of a common pin—is left to migrate within the unit it will pass through the capillary tubes, which are but 0.030 inch in diameter, where it will freeze and block the flow of refrigerant. It may do this in the first hour, or wait five years. Obviously, then, any simplification of refrigeration manufacture that improves the success of the drying operation makes for more trouble-free units.

Consider, then, the recent improvement obtained by making the filling with oil and Freon automatic. The old steps were these: an assembled unit, after many hours of evacuation, oven drying, blowing with hot, dry air, and re-evacuation, was filled manually with a measured amount of oil. Then the workman connected the refrigerant charging "bomb." This was a pressure vessel that had been previously carefully dried, evacuated, tare weighed and charged by weight with Freon-12 under pressure. The bomb is left connected to the unit in a low-temperature room, with close control of the temperature and humidity for a minimum of three hours to transfer its charge to the evacuated unit. All this comprised several steps and several manual operations. Failure to perform any one was difficult to ascertain.

Now the assembled, dried, evacuated unit arrives at the filling station with its production card. The operator does two things. He makes a simple clamp-on hose connection. Second, he places the production card in the filling machine. This action causes the machine to pump into the unit a charge of Freon-12 and oil within limits of 0.2 of an ounce. Further, it stamps on the card the amount of each and the time, to give a permanent, exact record. Nothing the operator can do can cause a machine to be skipped, be filled with an improper (or unknown) amount of either oil or gas, or filled twice. By bomb charging, the amount of refrigerant pumped into the unit could not be held closer than 0.5 ounce. With machine charging a tolerance less than one half that is easily maintained. With automatic-defrosting units this is important. Also, the whole charging operation, including the time for making and breaking connections, evacuating the charging gun head, checking the unit for vacuum and metering in the correct charge of Freon-12 and oil, takes about 40 seconds. Before, it required over three hours—but, most important, the charging bombs, their maintenance to free them of leaks, furnaces to dry them, and other steps that offer a chance for moisture to get into the act have been eliminated.

The initial drying operation, too, has been greatly simplified. Previously the drying was done after the unit had been assembled—and required some 12 to 16 hours. Now the major components are dried separately. Some are dried naturally in the painting or brazing process. Others can be dried more fully and much more quickly by doing so before they are sealed into the final assembly. Not only is there a saving of drying time, floor space, and ovens, but the product is better because some parts of the assembly—like rubber grommets and insulators—should not be heated. Incorporated into the production line are many more quality and performance checks. The result—fewer errors, a saving in material, and lessened production time.

New room coolers have improved controls, neater appearance.



More Versatile Room Cooler

THE NEW window-type room air conditioners have grilles that are individually adjustable to direct the flow of conditioned air up, down, right, or left—or any combination. Thus the air can be directed, in accordance with furniture positions, to eliminate drafts. The units are built in four sizes from ½ to 1½ hp. The ¾- and the 1-hp de luxe models have a two-speed fan motor, a thermostat control, and solenoid-operated exhaust and intake dampers. These two models also contain electric-heater elements to give them year-around serviceability, from a pushbutton panel with ten settings.

Preparing for the Coming of Color TV

THE PREMIER of color television is expected momentarily. Behind the scenes there has been a welter of activity; just as before opening night of a big play the actors, directors, set designers, costumers and scores of others are in a fever to make their portion of the coming spectacle the best possible. Some groups have been at work to develop better, larger, and cheaper color-picture tubes. Others have been attending to circuit problems while those concerned with cabinet design have been working to give color-TV equipment a beauty all its own. Of greatest importance has been the participation of engineers in industry committee groups that are formulating the standards and procedures by which the "show" will go on smoothly and to greatest public satisfaction. Since early 1950 several groups of engineers have been devoting full time to study of color television. A research group has been engaged in fundamental investigations, while development and design groups have studied basic circuit problems and have worked closely with the National Television Systems Committee on the compatible color television system recently approved by the FCC. Each step of the development was checked in field tests with NTSC. Another necessary phase of the preparations is the creation in the laboratories of equipment for producing standard color-TV signals for use by the development engineers. These are sizable affairs—in fact they comprise the equipment of a color-TV studio, except cameras (film is used instead), but with additional means of dissecting the signals into their many components for comparison purposes.

A New Idea in Metal-Cabinet TV

THE GENIUS of electronic engineers and the economies of mass-production methods is attested by the forest of antennas above the housetops of every TV city. The combined results are receivers of high quality and low cost. And the drive in those two conflicting directions continues.

One of the most stubborn obstacles to lower cost is the wood cabinet. Sets have been built of other materials, such as plastic and metal, with various degrees of success. A metal cabinet holds the greatest prospect of economy, but attempts to use it have usually run afoul of the psychological factor. Mostly the undoing of metal cabinets has been the attempt to make them resemble something else, usually wood—and these attempts never quite come off.

A new approach to the problem is simple: don't attempt to make metal look like mahogany or walnut or oak. Metal can be given finishes that are attractive in their own right. A new 21-inch table model TV set is built on this basis, with highly satisfactory results. Because the cabinet is metal it has been designed to take every advantage of production-line methods. The trim and finish make the set compatible with the finest of living-room surroundings. Or the set can be placed on a low base of wood supported on short metal legs of modern design. The front of the base has a grille behind which the more discriminating set owner can have mounted an extra speaker if he wishes.

Touch Control for Water Cooler

USUALLY a person approaches a water cooler with some wariness, turning on the bubbler control cautiously until he is sure of the response. With a dual-electric controlled water cooler one gets a drink without that element of uncertainty because the hand or foot control does not actuate the valve directly. Instead a feather touch by hand or foot operates a switch to a solenoid that opens or closes the water valve. Also, solenoid operation of the water valve eliminates one valve-stem packing, cuts down possible leakage.

Added protection is given the motors used in water coolers. In addition to the usual overload protection, the thermostat is made responsive to the current in the starting winding, which has very little heat capacity. Thus, if the relay fails to open, the starting winding is not burned out.

Materials

Left: **Test panels painted with high-temperature aluminum paint are given a torch test.** *Below:* **Silicone rubber diaphragms can detect extremely minute changes in air or gas pressure.**

A Paint That Meets the Welding-Torch Test

PAINT and high temperatures just don't go together. That is, they haven't. But there is an indication that they are going to be more compatible. An aluminum-base paint has been developed that can withstand 1700 degrees F—well above red heat of steel—for periods of a few minutes. Even after 300 hours at 1250 degrees F, followed by 120 hours of salt-spray test, a surface painted with it shows no rusting.

The paint itself consists of a silicone vehicle plus solvent heavily loaded with finely ground aluminum powder and certain chemical additives to control the mechanical arrangement of the aluminum flakes. The paint is flowed, brushed, or sprayed on the carefully cleaned steel surface. Following an air-drying period to drive off all the solvent, the surface is baked at a moderate temperature and a second coat applied, if desired. The aluminum becomes more than just a surface layer on the steel. In service at high temperature it diffuses into the steel surface, becoming an integral part of it.

The high-temperature aluminum-base paint has numerous applications: to jet-engine parts, to steam apparatus and piping, and to metal stacks from furnaces. Sometimes a product is more in need of protection during its manufacture than during its service life. For example, when metal is sealed to glass—as in a television tube—the temperature destroys the ordinary protective coatings on the steel, leaving it susceptible to subsequent corrosion in service even though normal operating temperatures are low. The new paint is useful for such applications. It can be applied to any kind of steel.

Thin Diaphragm to Meet Extreme Conditions

MATERIALS engineers get problems like this. A diaphragm is required that is sensitive to minute changes in air pressure. Further, the flexing of only a few thousandths of an inch must be essentially the same at −30 degrees C and at 110 degrees C as at room temperature. The diaphragm must (a) be airtight, i.e., no pin holes, (b) not absorb moisture, and (c) be able to withstand vibration and shock common to airborne apparatus.

Measured against these and other practical production requirements the common diaphragm materials—thin metals, natural and butyl rubber, and so on—fall by the wayside.

One of the silicone rubbers, however, has provided a satisfactory solution. Methods have been worked out for molding membranes of silicone rubber as thin as 0.005 inch to aluminum discs repetitively; these membranes meet all requirements. The process is a precision one, requiring extremely accurate control of process temperatures and times, curing-cycle rates, and a high order of cleanliness.

New Fields for Thermalastic Insulation

FOUR YEARS ago an entirely new type of insulation for high-voltage rotating machines was introduced. Known as Thermalastic, it consisted both of a new solventless synthetic impregnant and a method of applying it that insures com-

An alloy is rapidly analyzed with a fluorescent x-ray spectrograph.

A new insulation for metal-enclosed switchgear discourages fire. By comparison with conventional phenolic-resin insulation when exposed to an intense arc, it takes twice as long to ignite, and after the arc is removed, the flame goes out in one fourth the time. Such a paper-base insulation impregnated with a new synthetic resin may reduce somewhat the damage to a unit in which a short circuit occurs, but of greater importance is that it limits the chance that adjoining switchgear units will also become involved.

plete fill of all voids. This insulation, compared to the old asphalt-base, mica insulation, has much greater flexibility. It can move without cracking as the coil expands and contracts with temperature changes at a different rate than the core and frame. Also its dielectric strength and resistance to moisture and other atmospheric contaminants are many times better.

Several of the first turbine generators to receive Thermalastic insulation have been recently examined. In every case the insulation is in the as-new condition. This is true even of machines in peak-load service that have been started and stopped daily for several years.

The application of Thermalastic insulation has since been extended to waterwheel generators. Because these use full coils instead of half coils, different production facilities are required for its application.

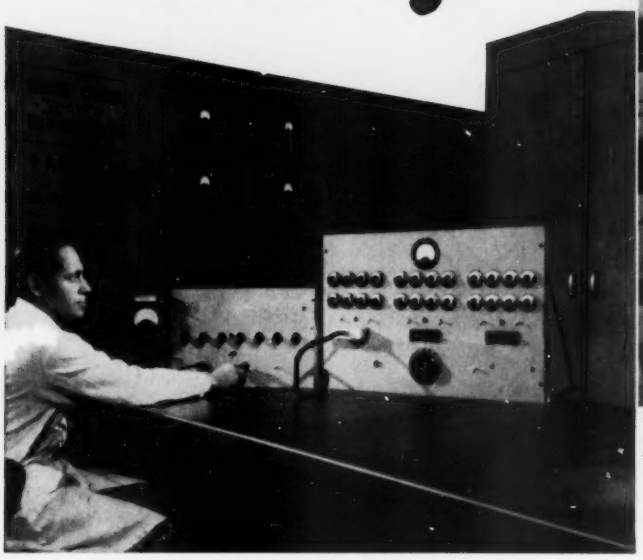
The success of Thermalastic insulation has been so outstanding that the synthetic impregnant has been modified slightly to permit its use on all large motors of whatever voltage, i.e., machines having individually preformed coils. The benefit here is not only in electrical strength, but also the vast improvement it provides in resistance to moisture, acid-forming gases, and even to conducting dusts. On a comparative test in which a Thermalastic-insulated motor and one conventionally insulated were sprayed with water for several hours, the insulation resistance of both declined, but the Thermalastic machine remained at a much higher level than the other. However, with the water shut off, and with no accelerated drying, the Thermalastic-insulation recovered its normal insulation resistance in a few hours; the other took several days to do so. This indicates that the moisture is only on the surface of the Thermalastic insulation but that it penetrates conventional varnishes.

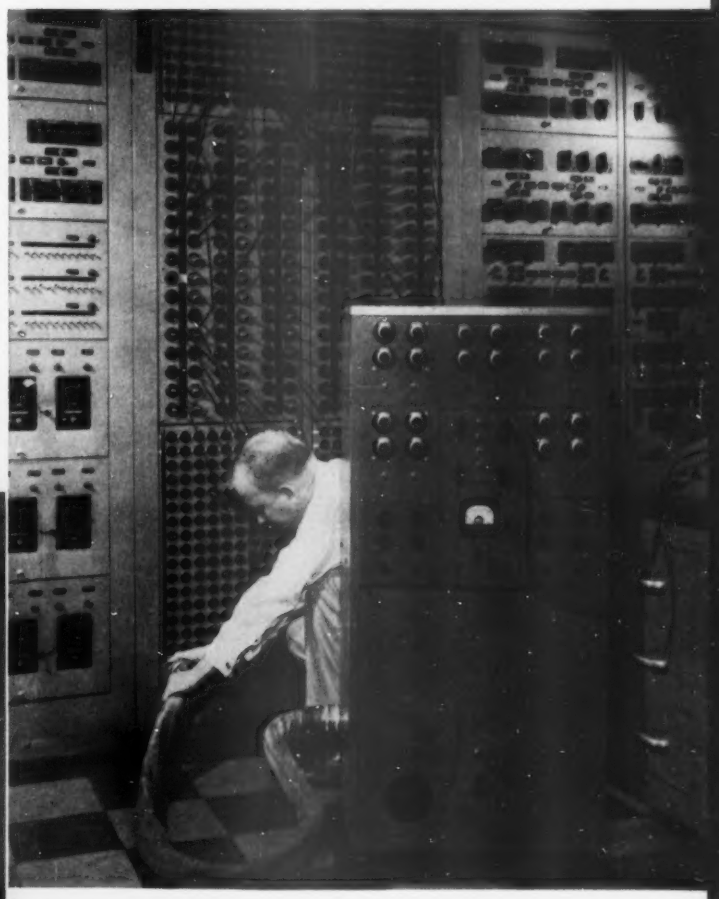
A New Tool for the Materials Engineer

A COMMON question facing engineers engaged in either development or production of alloys is, within close limits. What are the constituents of a given alloy? Take, for example, a material such as stainless steel or Discaloy, which has high percentages of chromium, nickel, and iron. How can one determine the proportions of each, within a fraction of a percent? It can, of course, be done by standard chemical methods —in, say, a day. But that mostly is too slow.

The new way is to do it with a fluorescent x-ray spectrograph. A beam of x-rays is shot obliquely at a small wafer of the alloy. This produces secondary rays, each combination of wavelengths being characteristic of a particular element. Thus the secondary-ray output is first separated by a grating crystal and then scanned through a 180-degree arc with a Geiger counter. The angle of the secondary ray identifies the element; the intensity—its amount. The method is accurate to about 0.3 percent for components existing in quantities of more than 5 percent in an alloy. A test is made in about 30 minutes. This method of analysis supplements the emission spectrograph, which is suitable for identification of small or trace amounts of alloy elements.

New Knowledge

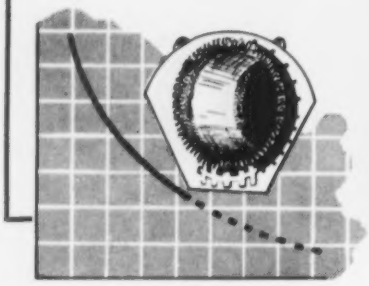


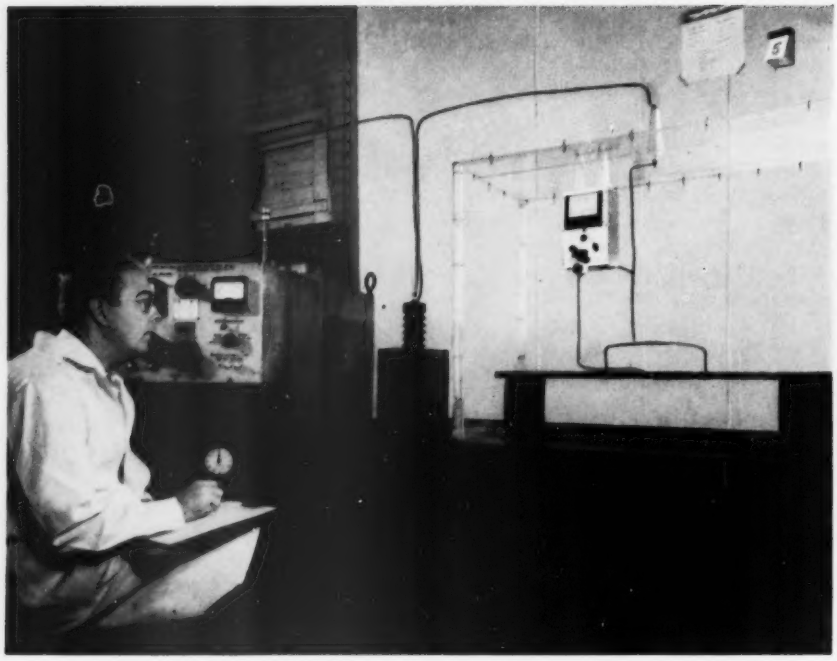


Above: **An electronic switch instead of a rotating machine now repeats transients for analog-computer study.** ***Left:*** **The special computer built for study of problems in the operation of pumping stations on long natural-gas pipelines.**

More Facts About Insulation

Insulation engineers now have a way of forecasting in many cases the dielectric level of a particular insulation without destroying it. The method is to apply to the insulation d-c potentials in steps, beginning with a low voltage. After stability is reached, at each level of applied potential, insulation resistance is measured. This gives data for a curve showing, usually, a declining resistance as test potential is raised. By stopping





Automatic Devices Speed Up A-C Calculating-Board Studies

AT SOME future time power-system studies may be made by feeding information on cards or tape to an a-c calculating board and the answers will come out in some recorded form. The operators will have only to prepare the initial data and cart away the solutions. That day, however, is still some time distant. Meanwhile, the operators have to turn dials, operate switches, and read instruments. But not as much as they did a few months ago.

In making a large-system study, operators become adept at setting the input conditions and reading results. They must, in order to minimize the length of time the board is tied up. In these studies, data—volts, amperes, watts, and vars—are read over a wide range of values. The operators must, in addition to feeding in data and recording answers, be alert to change instrument scales at the right time to avoid sending the pointers off scale or perhaps making an error. For long-experienced operators this becomes automatic, but for inexperienced men, or men in training, this function definitely slows up the studies. Now, scale changing on the ammeter, wattmeter, and varmeter is done automatically.

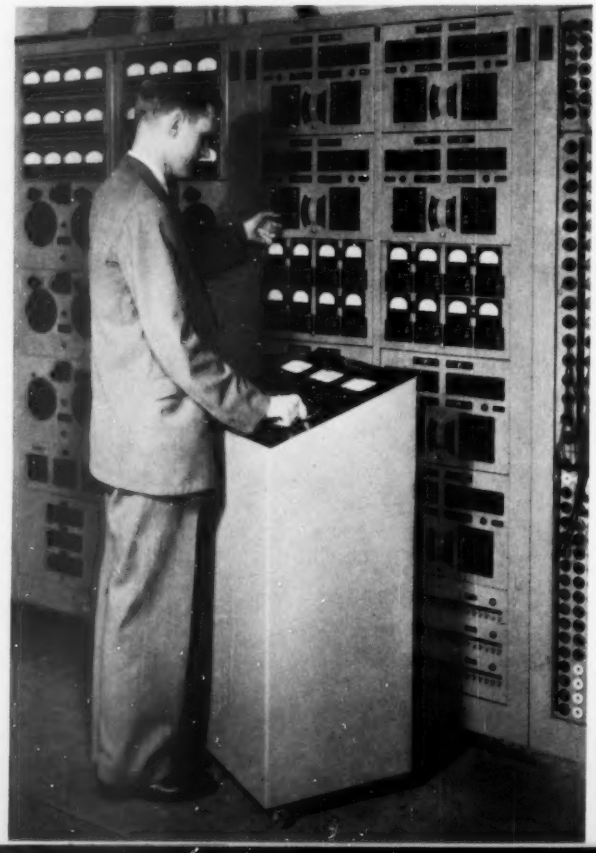
A-c board operation is further simplified and made more foolproof by an electronic polarity checker. It automatically insures that watts and reactive volt-amperes are fed to the wattmeter and varmeter at the right polarity. Further, it indicates the polarity by a steady-burning lamp for positive flow and a winking light for negative flow.

In the a-c board a number of generators acts as replicas of stations on a large system. Suppose a study is being made to determine, say, the effect of a change in load of one station. On the board this may affect the output of some of the other generators in a way unlike on a real system. It has been necessary to make manual readjustments to correct this. Now this will be done automatically by a newly developed watt regulator for each generator. Thus the board becomes a more faithful representation of the performance of actual systems.

Computers Are Busy These Days

THE CIRCLE of uses for computers is ever widening. An important new one is the establishment of power-system loss formulas and data for most economic load dispatching, particularly on large interconnected systems. The dispatcher of, say, a system or interconnected systems must operate the several generating stations over a complete swing of load conditions for greatest economy, considering power costs at

A mobile console allows a-c board load circuits to be set directly.



the test well before failure—and before insulation has been harmed—the curve can be extrapolated to determine, quite accurately in many cases, the voltage at which failure of that particular insulation will occur. This method, now under development, extends the hope that it may be possible to determine whether the need for reinsulated coils is imminent or whether considerable service life remains—and do this without consuming any of the insulation life.

This new insulation-test philosophy is based on laboratory tests on hundreds of insulation specimens of different types and ages under controlled conditions. From the mountain of data obtained has come the correlation necessary for judging the results of a test on the complex insulation of a rotating machine that has been in service, perhaps for many years.

the buses of the various stations and the transmission losses. This involves, first, a study on the a-c calculating board of system load flow. Then a so-called loss formula for the system is developed on the digital computer. By manual methods this would be almost impossibly involved; even for connected systems with only ten stations the loss formula contains 55 terms. Finally, on the digital computer and with the information accumulated in steps one and two, a schedule for most-economic dispatching for different load increments is made.

Such a study was developed for a fair-sized eastern utility. A dispatching program was worked out by which the system is being operated $60 000 more economically yearly than by the best previous manually calculated program.

Computers are being used also to insure that maximum advantage is being taken of the new principle of inner cooling of generators. Inner-cooled generators are different in several ways from conventional machines. They are physically smaller, with less inertia and higher reactances. These and other things have bearing on short-circuit ratio, system stability, relay settings, breaker operation, regulator requirements, and so on. The analog computer is being used for a complete study of all effects, including both dynamic and transient stability.

Computers are also being used more and more for automatic solution of many problems involved in the routine application of electrical machinery. For example, the duty-cycle data involved in applying motors to hoists and many others have been coded for solution on electronic machines.

Computers have been put to work on the innumerable problems in connection with blades of compressors and steam turbines. This began with the compressors for the Tullahoma wind tunnel, largest in the world, and have extended to steam-turbine blades of all types. The natural-frequency computations that form the basis of design and stress determination have been reduced from an arduous manual computation of several months to a machine computation of less than two days, for the several lower natural frequencies of a single blade.

Steam piping that is held rigid at both ends and perhaps at one or more intermediate points and with several bends poses difficult stress-analysis problems. The solution of 12 to 18 simultaneous equations is usually required. A nightmare for a human calculator! Duck soup for a computer!

Continuous Measurement of Low Vacuum

THREE and a half years ago the Bayard-Alpert ionization gauge was acclaimed as giving a major boost to low-vacuum research. It provided a means of accurately measuring pressures 1000 times lower than could be measured before.

A regulated current and voltage supply is ordinarily used to operate the ionization gauge. In the past, the practice has been to regulate electron currents at a convenient value of about 20 milliamperes. However, it has recently been recognized that the ionization gauge itself acts as an effective vacuum pump, and it may, therefore, seriously change the pressure being measured. This pumping effect is due to the fact that ions, once collected by the negative electrode, tend to be adsorbed, never returning to the vessel as neutral molecules. One way to minimize the pumping effect is to turn the ionization gauge on only when it is desired to read the pressure, leaving it inoperative most of the time. However, it is often necessary to monitor continuously the pressure in a system, and in this case the pumping effect must be reduced by greatly reducing the rate of forming ions, i.e., by reducing the electron current.

A new electronically regulated current and voltage supply has been developed that permits operation of the gauge at electron currents of one microampere, less than previously possible by a factor of 20 000. The resulting decrease in pumping effect greatly increases the accuracy of the ionization gauge and makes it possible to monitor experiments for long periods. The ionization gauge, therefore, more nearly approaches the ideal measuring instrument, which must have no effect on the system it measures.

Analyzing a Chemical Maze

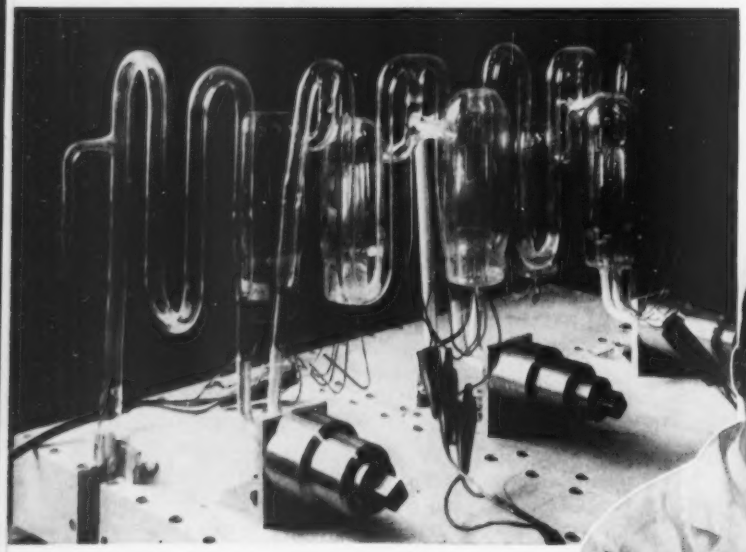
THE OLDEST and still one of the most extensively used synthetic resins is that produced by reacting phenol with formaldehyde. Although millions of pounds of it are formed yearly, relatively little is known about the reaction.

The formulation of a phenol resin looks, on the surface, simple enough. The starting ingredients are few—phenol, formaldehyde, and an acid or basic catalyst—although the possible proportions are many. But the courses taken by these compounds en route to the final resin are so involved that, by comparison, a complex maze looks like a broad, straight highway. At the outset some or all of five separate types of reactions take place. If these five simply combined to make the end product, the analysis wouldn't be so difficult, but wait! These five (or less) secondary compounds start reacting with each other. And these tertiary products then start to interact and so on. In a very small jiffy (at commercial reacting temperatures) the possible number of different products is up in astronomical figures. Then, with similar promptness, the diverging reaction paths begin to converge, resulting in a particular final relatively stable resin.

The hitch is that the properties of the final resin depend on which of the nearly infinite routes predominated in its genesis. The chances are that most resins are mixtures of many of the possible intermediate steps, and one commercial resin differs from another in that by the particular process used certain steps are induced to predominate.

The trouble is, there has been no satisfactory method of analysis of complex paths followed by the molecules in a given case. The application of a fairly simple but astonishingly precise process bids to end many of the uncertainties that have shrouded this branch of chemistry for nearly a half century. The process is called paper chromatography. It isn't new, either, but it has not been applied before to this field.

To study one of the innumerable possible formulations, the phenol, formaldehyde, and catalyst are mixed in the usual way, but held at room temperature. The reaction to form resins begins, but at a slow rate because of the low temperature. At intervals, small samples—extremely small samples, amounting to only about ten micrograms—are taken and the reaction in the sample stopped at that point by dilution. Each set of samples is dabbed near the top edge of a large sheet of ordinary filter paper suspended in a covered jar. Resin solvent is allowed to flow slowly down the sheet. The solvent moves downward, picking up the tiny dab of sample. Now here is the trick! Each compound in the unfinished resin—held, as it were in a state of suspended animation—moves down the filter paper at a rate of speed as characteristic to it alone (because of differences in molecule size) as a fingerprint is to its owner. Thus, in its downward movement each dot sample acts like a horse race. The several components proceed at different rates. Soon the separate components are strung out at intervals along the "track." After the "race" is allowed to continue a given time, the paper is removed and painted with a chemical that brings out the locations of each component. The color and locations positively identify each compound originally present; the size of each dot determines its amount by measurement or by cutting it out and weighing it. Thus by a succession of paper chromatographs for a given formulation, the sequence of reactions from start to the final resin can be ascertained. The process is simple, but its accuracy is astonishing. The prospect is plastics by design instead of by cut and try.



Ionization gauges can now measure low vacuum continuously. At their base are new leak-proof valves.

By a technique known as paper chromatography, research chemists are analyzing the extremely complex sequence of reactions by which phenol and formaldehyde combine to form the commonly used impregnating resin. Each dot on the paper indicates the presence of a chemical formed en route.

RESEARCH AND DEVELOPMENT

...behind the scenes

The industrial machine in this country operates in much the same fashion as an automobile engine. Its three functions, research, development, and manufacture—which usually follow in that sequence—can be likened to fuel injection, compression, and firing of a gasoline engine. Further, both depend for their operation on proper timing of these operations. If one lags too far behind the others, the machine does not function smoothly, or perhaps comes to a dead halt. In the case of industry, research, development, and manufacture must proceed in some semblance of synchronism—new knowledge must be uncovered, i.e., fuel must be provided, the new knowledge must be converted to useful devices, and manufacturing methods must be devised.

Mostly, in this review of new things, the emphasis has been on the output of the engine, the specific products or devices. These are the things of immediate interest. But equally interesting stories could be told of the work going on toward tomorrow's products. Consider these examples.

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Nothing is more basic to the electrical industry than magnetism. While theories have been propounded to explain it, the fact is that most magnetic materials in use today are the result of processes developed by experience. Magnetic materials are not designed.

A few years ago, Dr. Clarence Zener, a theoretical physicist, offered a theory of magnetism based on a new concept of the atom, which in his hands and those of his associates is being used very successfully to understand the properties of known magnetic materials and to tailor entirely new ones.

Research scientists have forced three of nature's elements—in definite proportions—into combination under heat. One of these is a metal (not iron) and two are nonmetals—particular combinations never before used as a magnetic material. The final result is a small vial of powder—hardly enough to fill a thimble and certainly not enough for a single magnet of any consequence. However, these little black grains cast a long shadow in that direction—for they display properties of very high coercive force and high saturation—with the promise of leading to magnets significantly better than present commercial ones.

The research effort is only in its beginnings. There is a long road between a thimbleful of powder and a new magnetic material available in pound or ton lots to designers at an economic price. However, the early, and yet inconclusive evidence, suggests that the Zener theory may offer a way to formulate magnets by design.

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Those who deal with high-temperature machines have long looked hopefully at molybdenum as a possible answer to their need for a material that has good strength at temperatures in the neighborhood of 2000 degrees F. One of its weaknesses is its proneness to oxidize when hot. But another stumbling block to its use is a characteristic that shows up not when it is hot, but when it is cold. Most metals become brittle at low temperature, but moly has the annoying characteristic of being brittle at room temperature—a fatal defect even for a turbine or jet engine.

Incompleted research indicates that, by careful control of grain structure and by strict attention to impurities, it will probably be possible to depress the rather sharp temperature point where brittleness occurs, to a point well below normal machining and operating temperatures.

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It is a real trick to amplify feeble signals down to a billionth of a watt—even for electronic devices, much less with static, magnetic devices. However, it looks like that won't be so long. Apparently no one told the magnetic-amplifier boys such amplifications aren't possible. They are building low-level amplifiers using completely static devices, such as selenium rectifiers and magnetic amplifiers, that can faithfully amplify signals as weak as only one billionth of a watt. To do this they are using magnetic amplifiers wound with size 49 insulated wire (one mil thick—less than a human hair). This is put on a miniature core as small as a pencil eraser. The core is wound of Permalloy strip that is only one eighth as thick as the wire—0.000 12 inch. It would take 30 layers of this steel to equal the thickness of paper these words are printed on. Engineers hope to achieve electronic-free amplifiers that work directly from the output of thermocouples and similar low-energy devices.

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Oil that behaves like a steel spring! Although the spring-dashpot actions of journal-bearing oil films have been recognized for some time, recent increases in the operating speeds of blower drives to 8000 to 12 000 rpm have necessitated better understanding and control of these actions. These turbines, which range in size up to 15 000 hp, run between the first and second critical speeds; hence the spring action of oil films can lead to trouble by lowering the second critical speed into the operating range.

Extensive studies of this phenomenon are resulting in considerable new knowledge of the behavior of rotors at critical speeds, and are also providing data for more realistic computations of critical speeds.

Changes in turbine design are being employed to minimize the troublesome effects of these oil-film properties.

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Occasionally, as happens to the best of machines, the industrial engine gets out of synchronism. Sometimes it's even intentional, as for example during the periods of war, when certain areas of research become more vital than others, and are therefore speeded up. Fortunately, however, the industrial engine has tremendous momentum; also the fuel supply always seems sufficient to provide for progress even with a temporary lack of new knowledge.

These few examples, from hundreds available, may serve to illustrate that the initial actions of the industrial engine—research and development—although not emphasized in this review, are functioning properly.

ELEVATOR SYSTEM IN MINIATURE. This scale model of a four-car elevator bank performs precisely as would a full-sized automatic traffic-pattern system serving a ten-story building. The model's electronic "brain" analyzes prevailing conditions, then sets up the most suitable traffic pattern.